The option to spy: The Firm Behaviour, Global Welfare and Policy Measures

by

Tiago José Barbosa Marques, 201500283

Supervised by:
Paulo Jorge Marques de Oliveira Ribeiro Pereira, PhD

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Faculdade de Economia, University of Porto

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Bibliographical Statement

Tiago José Barbosa Marques is 23 years old and was born in Guisande, a small village of Braga, Portugal. He completed the Bachelor degree in 2015 in School of Economics and Management of University of Minho (EEG-UM).

After completing the bachelor degree, Tiago enrolled in the Master in Finance program of Faculty of Economics and Management of University of Porto (FEP), whose dissertation is the last stage of the program.

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Abstract

The market leadership by enterprises that actuate in the market is increasingly as a main objective. This position of the company allows superior levels of profitability and stability of future revenues. Although, the high competition that is felt in the world markets and the political turmoil thicken this task of the firm to maintain the front position in the future, leading to a search of potential solutions. Inside of this set of alternatives, the corporate espionage might be preferable. The choice of this solution is more and more frequent, where the scandals and espionage activities are performed by largest companies.

The uncertainty, flexibility and irreversibility corroborate the use of Real Options Approach with the aim of calculate the optimal timing to incur in espionage, for a specific optimal level of these operations. On the first stage of the model, we assume that the company, as an individual agent, decides to use these activities for maximizing its value. However, the maximization of the value of the firm deteriorates the social welfare, which leads to the active attitude of the regulator in order to determinate the social optimal timing to the occurrence of espionage actions, as well as define the differences between the efficient and social optimal moment. To combat the incentives of efficient solution in relation to social equilibrium, the state might intervene *via* suppliers or consumers.

The results of this study demonstrate that the cost structure of the production and espionage postpone the optimal decision of incurring in espionage, while the production cost disparities between the firms anticipates the performance of these actions. The expected probability of success or the intensity of these operations is only affected by the level of uncertainty surrounding the market. However, the firm detains incentives to decide efficiently instead of securing the social interests. To protect the social welfare, the regulator might apply a system of consuming subsidies or finance the defence of the competitive vantage of the peer.

The theoretical evidence founded throughout the model allowed a significant contribution to the literature, once it is one of the first model that does not state a fixed position concerned with social implications of espionage, *i.e.*, the timing to incur in these activities determines if espionage is beneficial or harmful for the society.

Key-Words: Real Options, Corporate Espionage.

JEL Codes:G11; G13; O16.

Resumo

A liderança dos mercados por parte das empresas que o disputam é cada vez mais um objetivo primordial. Este posicionamento permite à empresa elevados níveis de rentabilidade e de estabilidade de receitas futuras. Contudo, a elevada competição que se faz sentir nos mercados mundiais e a conjuntura política e financeira dificulta a tarefa das mesmas em manter a sua posição estável, levando-as a procurar soluções estratégicas diversificadas. Dentro deste conjunto de alternativas, a espionagem industrial pode ser uma delas. A escolha desta solução tem sido cada vez mais frequente, onde os escândalos e atividades de espionagem são desempenhadas por grandes empresas do nosso quotidiano.

A incerteza, a flexibilidade e a irreversibilidade da espionagem justificam o uso de um modelo de Opções Reais com o objetivo de determinar o momento ótimo de realizar estas atividades, para um determinado nível ótimo de sucesso destas operações. Numa primeira fase, é assumido que a empresa, como agente individual, decide o uso deste tipo de atividades com o intuito de maximizar o seu valor. Porém, esta maximização deteriora o bem-estar social, o que leva à participação ativa do regulador para determinar o momento socialmente ótimo para a sua realização, bem como determina as disparidades em relação à decisão eficiente da empresa. Como forma de combater estas diferenças na ocorrência ótima de espionagem, o estado pode intervir *via* produtores ou consumidores.

Os resultados deste estudo demonstram que a estrutura de custos operacionais ou de espionagem atrasam a ocorrência deste tipo de atividades. Por outro lado, a disparidade de custos entre as diferentes empresas antecipa a realização das mesmas. O nível de sucesso ou a intensidade destas operações apenas é afetado pelo nível de risco do mercado. Todavia, a empresa tem incentivos a decidir eficientemente em detrimento dos interesses sociais, o que leva o estado a aplicar subsídios ao consumo ou o financiamento da defesa da vantagem competitiva da concorrência.

As evidências teóricas encontradas ao longo do modelo permitem também uma contribuição significativa para a literatura, uma vez que consiste num dos primeiros estudos que não defende uma posição fixa no que concerne às implicações da espionagem na sociedade, ou seja, o momento de realização das operações determina se a espionagem é socialmente benéfica ou nefasta.

Palavras-Chave: Opções Reais, Espionagem Industrial.

Classificaes JEL: G11; G13; O16.

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Chapter 1

Introduction

The world economic environment is, in most industries and countries, increasing with the competition and each firm tries to fight with all the tools to lead the markets, in innovation and profitability. The global competition, the flexible currency and international markets, the political turmoil, the uncertainty behind the country recession reinforce and boost the pressure of the market (Vashisth and Kumar, 2013). This position in the market is not accomplished only to the high level of efficiency in the company. The larger amount of information about the market as a whole and the behaviour of each competitor/firm that can have a direct or indirect effect in the position of a specific company can lead into a unique position to strategically decide what the best action to incur. Commonly, the strategic unit of the company should decide how the company intervene in the market and balance the use or not of these activities.

Sarangi et al. (2010) argues that the systematic and ethical approach of a specific company to gather, analyse and monitor information that can affect the firm's plans, decisions and operations performed by the legal competitive intelligence business actions is insufficient. It is required a deeper level of specific information in order to gain a significant advantage in relation to others firms. Thus, with the aim of achieving a larger amount of information about the competitive environment, the company shelves the ethical values that can sustain the activity. This fall leads to a blurring in the intelligence activity of the company, being difficult to understand the threshold between the ethical and legal activity and the illegal actions powered by the firm. This information and its collection need to be pre-emptive of any event and decision. Only in that situation it can be favourable to the firm. Thus, as decision process pre-dated the possible move of the competitor, *the real threat* for the company , industrial espionage might be taken into consideration (Solan and Yariv, 2004). This questionable method of gathering information via illegal and unethical means can lead to a better performance and to maintain the competitive edge (Vashisth and Kumar, 2013).

The first known case dates back to XVIII century, where *Père D'Entrcolles* monitors the manufacture process of Chinese Porcelain, meticulously (Finlay, 2010). After that, the number of corporate espionage attacks are becoming larger, being nowadays, situations that happen frequently. Almost 8.5 billion of dollars is how much the American Companies bear annually due to the costs of espionage (Chen, 2016). The method also is more advanced than before (based on the observation and the technical contact) and now in actions like waste sifting (dumpster diving), surveillance devices installation, (Vashisth and Kumar, 2013). The case of spying activities of Proctor and Gamble Company in 2001 are an example of this development. In order to obtain information about the direct competitor Unilever PLC, they decided to search in the shredded documents (Vashisth and Kumar, 2013).

However, the espionage is well-known by the companies since the beginning. Even Boulton and Watt, in XVIII century, knew that any company or other scientist could steal their knowledge and information about the steam engine invention (Birch, 1955). Also, Opel division of General Motors Corporations knew that the inclusion of former employees in a direct competitor, Volkswagen Group, might have as a principle the sharing of their knowledge, in 1993 (Vashisth and Kumar, 2013). Sarangi et al. (2010) states the awareness of the possibility of being victim of espionage by other related enterprises. The understanding of this reality lead the companies to fortify their defences against such attacks. These attempts by the companies are sometimes useless against a complex spying strategy. Although, and taking specific circumstances, the victim might not prevent such actions of the competition or other firms. Sometimes, the *insider threat* is a reality and the company is not able to prevent these actions. Hewlett-Packard Company already had cases with this characteristics.

The ethical and legal perspective in espionage comprehends a critical importance to the society. However, the growing concern about the effects of espionage might injure the long run perspectives of a company, or even a country, (Sarangi et al., 2010).

The importance of the industrial espionage is also highlighted by the macroeconomic study of Cozzi and Spinesi (2006). According to them, the corporate espionage deteriorates positive effect created by the R&D activities of the enterprise, and allows a higher differentiation in the products develop in specific market. This differentiation result of the weakening process of the R&D activities, that could boost the economic growth. This study corroborates the conclusions obtained previously by Cozzi (2001). Taking into consideration the implication for the economic growth of the spying activities, Cozzi (2001) was able to explain that the implications of the incentives to spy increase as the number of skilled employees rise. This kind of behaviour, in the opinion of Cozzi (2001), enables a quick process of diffusion in the economy. Segerstrom (1991) already tried to study the impact of these activates. According to him, the imitation process is an interaction between a leader in a product with a high level of quality that will be copied by other enterprise in order to decrease the amounts of profits. However, this behaviour is more common when the process of innovation is less costly, *i.e.*, when the process of innovation is higher, the firms will focus on their products and decrease the amount of espionage.

As it is possible to realize, the economic environment that different enterprises are facing shows the need for them in searching for solutions. However, in what concerns to the theoretical evidence, the scope of espionage activities is quite scant. The managerial and economic implications of such activity are not much studied, which is a challenge for the present study. Based on the established literature gap, the aim of this study is to develop a model able to study the optimal timing for the firm to incur in espionage operations.

As soon as the start of espionage activities is decided, the consequences of such action are irreversible, with an influence in the profitability and sustainability of the spy corporation also for the market. The impact of such activity is also uncertain, *i.e.*, the influence of espionage in the future of the company is quite unpredictability. Although, the company, specially the managers of the enterprise, are quite flexible to choose when it is more beneficial to carry out these activities.

These three characteristics of the managers' decision validates the Real Options Approach as the method for our model. The determination of the optimal timing to spy is based on the option to espionage, *i.e.*, the manager has the right, but not the obligation of incurring in such activities (Dixit and Pindyck, 1994).

However, the efficiency of this decision is not a guarantee of the equity for the society. The enforcement of these operations might not bring benefits for the different agents in the market. In order to guarantee the maximization of the welfare of the society, is required the intervention, implicit or explicit, of the government. The inclusion of a regulator goes according the empirical evidence, with the aim of ensuring that the interests of the society are taken into consideration. Thus, we also decide to develop the optimal moment of espionage for the enterprise, but with the guarantee of social equity, at the expense of profit's maximization.

The reminder of this dissertation is structured as follows. The following chapter presents the literature review of the main topics of the report, namely the espionage approaches and the different economical implications of theses operations. Chapter 3 presents the efficient model of the decision of the company to incur in spy actions and its implications. Chapter 4 exhibits the social decision model of the occurrence of spy actions, its implications and different instruments that allow the equality between the efficient and social solution. Chapter 5 concludes the dissertation, presenting the main contributions and conclusions of both models, and possible topics for future research.

Chapter 2

Corporate Espionage

"There is no place where Espionage is not possible."

Sun Tzu (V century BC), Art of War

2.1 Definition

The position of a company in a specific industry is increasingly important. Sarangi et al. (2010) denotes that corporate espionage is a comprehensive concept that embraces activities related with the theft of proprietary information. To Vashisth and Kumar (2013), industrial espionage an organization or a specific corporation must comprehend the actions of acquiring private information (classified or confidential), without any knowledge or permission of other company from which information belongs. This information can be part of the most fundamental parts of the output production (techniques, costs, recipes or formulas, levels of quality in raw materials), strategic plan (actions or companys decision, timetables of the next steps, business plans), customer relationship (customer databases, pricing list, marketing strategies) and R&D process about the spied competitors (Vashisth and Kumar, 2013; Barrachina et al., 2014). According to Kish-Gephart et al. (2010), this behaviour that widely violate the accepted moral norms and illegal acquisitions of information can be also described as the act of collect and manage sensitive information of the competitors to gaining or maintaining a competitive edge in the market (Vashisth and Kumar, 2013).

Nowadays, the espionages attacks are more concentrated in immaterial assets. According to Cozzi and Spinesi (2006), the fundamental and critical assets are immaterial/ intangible and this kind of assets are easily stolen than traditional/physical factors. These authors also argue that the critical assets able to misappropriation are those which can bring economic benefits to their authors but the property right is not yet established. Quah (1999) also emphasizes this aspect. The increasingly importance of intangible assets has been highlighted in the last decade, due to the easiness of stealing this kind of information, which in most cases is worth millions of dollars. Sarangi et al. (2010) emphasizes that industries that based its activity in this kind of assets, such as high-tech, pharmaceutical and drugs, defence related industry are more subject to this type of activities.

2.2 Why Companies Spy?

The espionage act sometimes covers a wide range of strategies that spying companies possess in that moment. Barrachina et al. (2014) states some of them after citing some newspapers articles about the subject. The cost advantages are one of them, once that the spying behaviour is more favourable, in some industries, that the research and development of the specific products and also it is necessary to take into consideration the cost related to the time necessary to perform R&D activities. This cost embraces the time that company would need to reach the development stage that observes in the competitors. Whitney and Gaisford (1999) states that the reduction of R&D expenses due to the economic espionage leads to direct benefits to the company, but it does not change the corporate strategy of the company, once that the strategy of the firm will remain unchanged. Sarangi et al. (2010) also highlights the role of economies of scope in order to motivate spy activities. When it happens a fall in the cost due to the production of more than one product (the benefit of knowledge across markets), the level of espionage is only determined by the costs of such operation (qualitative equilibrium specified by the cost). These authors also study the non-existence of economic benefits of diversification. According to a specific scenario of diseconomies of scope, companies will not undertake spy activities even when the intelligence cost is zero. The company, under this circumstances prefers to be spied by the peers.

Vashisth and Kumar (2013) also emphasize this reason as primordial to the spying act of a firm. They state that the bribery of an employee with the aim of stealing information is less costly than the development of a new product line with a larger investment in R&D. The insider threat is seen, by this authors, as an important area of industrial espionage. Cozzi (2001) also highlights this kind of behaviour inside the company, which justify the larger portion of the attacks in that time. According to him, the skilled-workers owns expertise about the subject/innovation process and try to reveal it to the competitors of the firm that have generating it. This kind of behaviour explains the espionage attacks suffered by Hewlett-Packard in 2006, that ended with the resignation of the chairman of the company, Patricia Dunn. Also, some of them, taking into attention Bhidé (2003), takes this information and initiate its own company. This kind of behaviour, *i.e.*, the replication on the modification of an idea encountered in their previous employment is responsible for the creation of 71% of the Inc.500s companies in 2000 (a list of young fast-growing firms).

Related to the costs of R&D and the production cost are the government subsidies for innovation or imitation. According to Segerstrom (1991), an increase in the innovation subsidy of the government increase the steady-state intensity of the imitation effort of each competitor (*i.e.* cheaper innovation implies a faster rate of imitation). The opposite situation also happens. An increase of government subsidy for imitation activity, each company will increase the innovations activity.

Another possible explanation related with the cost advantages is the production method of the company. Whitney and Gaisford (1999) study the case of spying activity between two worldwide airline corporations, where one of them spies the other in order to replicate the same technology with a lower level of costs. According to these authors, the production process or methodology induces two kinds of benefits to the company; strategic benefits resulted from the lower marginal cost, and also direct benefits due to the fall in the total costs of the company. According to Vashisth and Kumar (2013), this information can be used as a foundation to the innovation process of the company. Directly related with this reason is the ease of imitation, according to Segerstrom (1991), corporations should expect difficulties in the invention of a product/technology. But, in what concerns to the imitation, the ease of companies can imitate new products affect the incentives to imitate and innovate.

The enhance of the quality can also substantiate such happening (Sarangi et al., 2010). According to this study, spying activities can be motivated by the desire of the enterprise to improve the quality of the product. By this activity, the enterprise take notice about the rivals product, process and marketing operations. The improve of such characteristics of the product is impinged in the market by a boost of the companys market share. Sarangi et al. (2010) states that the spying activity or even the investment will intrinsically lead to a rise of the demand which implicitly increase the prices.

Barrachina et al. (2014) also addresses the market position to motivate spying activities. Depending from comparing who is spying who, the result in the market can be the increase of the markets power for some companies (if the spy is one of the major companies) or also the increase in the competition (if the small size companies try to observe the actions of the best players in the market). These authors, through their models give a related statement to this topic. Based on the entrant of a competitor in a monopoly market , their study state that (Barrachina et al., 2014, p.129):

> *When the IS (Intelligence System) accuracy is known only to the entrant and this information is very asymmetric, market competition is increased since the entrant is more likely to enter.*

So, when the asymmetry of information is favourable to the smaller companies or the companies that try to enter in the market, the possibility of increasing the market competition is larger. The rising level of competition can lead to better condition for customer, once that, as the increase of the competition, the market price decreases and the market output rise. This intuition leads to the increase of the customer surplus (Barrachina et al., 2014). The theft of information concerned with the market position of the company as contract bids, marketing plans, can rise strategic benefits in the global markets but no direct benefits (Whitney and Gaisford, 1999). Vashisth and Kumar (2013) also states that the information obtained might not be to the increase of the markets role of the company who spy, but to deteriorate the market position of the spied firm. The market environment can also justify the decision of spying or investing to the company, according to Segerstrom (1991). The author argues that in a single-leader industry, the company should imitate rather than investing, while in a two-leader in the market, the company, taking into consideration its profitability, should invest/innovate.

Another pertinent question can be the company safety. Taking into consideration the model of Barrachina et al. (2014) the entrant, in general terms, enters in the market if the monopolist (incumbent) does not invest in the expansion. Thus, in order to protect the sustainability, the entrant needs to know what the incumbent will do next. According to the study of Segerstrom (1991), it is possible to identify another related reason to motivate the economic espionage: the success of others firms, mainly peers. This company is attracted by these profits, and thus, develop the R&D and the production of new products. However, some companies are not prepared, so they spy the successful corporations in order to take ideas about how they can design the new products. The motivation can also be not only the success of a brand, but also its power and dominance in the market. We can designate this effect as *placebo effect*, where a company very well-established in the market and with a strong brand is spied only because this dominance in the market.

2.3 The Presence of Spying Activities in the Literature

Industrial espionage endures in the human history since the beginning of the corporate activity. The effects or the process behind the spy activity are not extensively studied in the literature. According to Chen (2016) the models behind the espionage activity can be incorporated in two categories, Non-Noisy Signal Model or Noisy-Signal Model. The difference, according to Chen (2016) is in the relevance of information quality and confidence. In the first typology, the models assume a binary condition to the information and the spying activity. In case of success, the information is assembled via espionage intelligence are always correct, independent of the conditions of the spy activity. In the case of failure, the information is not obtained, incurring into a sunk cost. The study of Matsui (1989) is encompassed on this trend. Based on a two-player repeated game, the adaptation or the breach on the prevailing market conditions are dependent on the myopic vision of other players actions.

Whitney and Gaisford (1999) also analyse the impact of corporate espionage based on this approach. The duopoly competition between two airline enterprises supported by the Domestic Government robust the developed study of this phenomena. According to this study, the incurrence of the monitorization of competitor activity is aimed by the technologic transfer and the human capital/knowledge behind the level of costs bear out by the peer. The Intelligence System accuracy is public which results in a random success or failure of the IS outcome.

Sarangi et al. (2010) emphasizes the importance of spying activity *la Cournot*, with an independence of the information quality. More specifically, these authors argue that the information provided by the spying activity is prior to the competition in the market. In a first stage of the model, companies decid the total amount of espionage. In a second stage, firms play a two-market Cournot Game, with inter-related cost between both markets.

The Noisy Signal models denotes another relevant topic in the occurrence of this activity, the valuation of the information received by the intelligence activities. In this typology, the models recognize the noisy signals received by the espionage activity, defining the level of accuracy of this method.

Solan and Yariv (2004) valuate the spy activity according to the this type. These two authors try to elucidate the advantages or the modifications if one player (based on two-player-game) can purchase noisy information about his opponent decision. Through Game Theory Approach, specifically based on a one-shot-game or a two-stage sequential game, this study explains that espionage is costly and provides a noisy signal of the spied company decisions, might leading to a profitability of the spy company. If it is common knowledge, the espionage activities cross the advantages of both players.

Provan (2008), based on this approach compute the effect of espionage in the process of entry deterrence. The entry deterrence, in other words, the decision process of the entrant to initiate its activity in some market based on the industry conditions, is one of the most discussed topics. Based on linear programming approach and with an interaction between two agents with a non-value creation (zero sum game), this author states a different solution of the previous one.

Barrachina et al. (2014) investigate also this subject and the effects of espionage in the decision. Through a Game Theory approach, the authors explain the decision process of the entrant based on the signal-jam received by the IS that monitors the monopolist decision of investing in an expansion or not. According to that, the entrant only benefits from the spying activities if the IS accuracy is high and the level of accuracy is known only by them. If this happens, the entrant enters in the market with a high probability which increase the market competition. If the IS accuracy is common knowledge, the incumbent can manipulate the signals emitted which can distorted the trust of the entrant in this system, which worst the entrant position.

Biran and Tauman (2009) also focused in this topic, but related with the role of the intelligence in nuclear deterrence. To these authors, the espionage and the monitorization of the competitors actions are unique and fundamental.

Barrachina et al. (2014) cite Mezzanine Group (2010) as a real illustration of this situation. Most of the companies research and monitor the behaviour of other competitors with the assistance of a market research firm (*e.g.* Mezzanine Group). According to this study, a possible entrant in energy market in Ontario is assisted by this kind of firms. So, the consulting company evaluate the competitive landscape of the geographical space, and some of the information given were the incumbent companies strategies to the area.

Another important aspect of spying is the possibility of this activity being manipulated and being sold for the best proposal. Ho (2008) studies this phenomenon, describing as double crossing events. According to her study, the spying activity is based on the rational and strategic decision, so the possibility of double crossing is real. This paper emphasizes the possibility the possibility of information can be sold for the rivals companies.

2.4 The role of Espionage in the Society

Economic or Industrial Espionage is possible through a range of military technologies and others behaviours or tools that can re-establish the balance or also increase the industrials disparities. Thus, espionage has the possibility of changing the *status quo* of an industry being able to create desirable effects and/or profit-shifting effects in very restricted markets. But also, is an unethical and illegal activity (Barrachina et al., 2014). Cozzi (2001) also states a social benefit role of industrial espionage, in a certain level of espionage. In a specific level, corporate spying can lead to a quick diffusion of the idea in the market (taking into consideration the intangibles assets idea), which can rush new products development. Solan and Yariv (2004), through a Game Theory approach, specifically through chain-store examples, where both players can access to espionage activities or only one can do it, discovered a efficiency improvement based on espionage activities, for a low cost of information. In other words, if the espionage is very cheap, it can lead to a Pareto improvement. Whitney and Gaisford (1999) states a social improvement caused by the espionage. Taking into consideration state espionage if both countries spy each other, it is possible an enhance of the economic conditions due to the technological transfer that is implicit with espionage. Also, consumers will be better off. For the companies, these two authors defend that economic espionage can have direct benefits, resulted from the access to valuable economic secrets, but also another kind of benefits. The common shift profits provide a common objective to the company.

For Crane (2005), the illegal acquisition of information is not favourable to the commercial interest of the source organizations and it also against the public interests. Mike McConnel, Michael Chertoff and William Lyn in 2012[1] also emphasizes the bad effects of industrial espionage in the market. According to this newspaper article, the quick growth of economic espionage can cause long-term injuries to the companies, damaging the competitor business drastically. For example, the Annual Report to Congress on Foreign Economic Collection and Industrial Espionage from Organization for Research Integrity stated that the economic espionage costs almost $100 to $250 billion in lost sales, in 2000 only to US Business Community.

The enhance of quality provided by the spying activities, according to Sarangi et al. (2010), might not bring beneficial repercussions to the social welfare and the consumer. The efficiency in the operational costs afforded by the espionage for the spy activity do not directly translate into a social welfare improvement.

In what concerns to the spy company, with its announcement, the credibility and the reputation is compromised, losing the organization and corporates integrity (Vashisth and Kumar, 2013). Also, as a consequence, the next negotiations can be seriously injured once that the partners or even the peers can hesitate to do business with this firm or also in entering in a specific market due to the fear of being spied. According to Winkler (1997), organizations should take efforts for preventing this kind of behaviour and also personnel, physical, technical and operational actions. This fair and ethical environment can help all the agents in the market. To Cozzi (2001), the spying activity socially deteriorates the redistribute activities, if the marginal benefit of spying is too large in comparison to the innovation. This author also states that the maintenance of a social environment that emphasize the innovation can be extremely difficult.

In spite of being notorious the different positions pondered by the previous referred

[1]http://online.wsj.com/article/SB10001424052970203718504577178832338032176.html (accessed 20.11.2016)

articles, Chen (2016), conclude an ambiguous effect in the consumer welfare. This statement is originated by the opposition of two effects, the technology transfer and the effect of the of the cost reduction investment. In other words, the espionage reduces the costs but it creates a positive effect to the costumer, appointed as technologic transfer effect by Whitney and Gaisford (1999), and one negative, related with the reduction in the investment focused in the reduction of the cost. The expected effect comes from the dominant effect of both.

The debate between the pros and cons against espionage highlights the importance of regulation in the corporate intelligence activities (Sarangi et al., 2010). Also, the heterogeneous equilibrium between what efficiently and what socially matters, *i.e.*, the equilibrium level can be different from the social optimal level, imposing the pertinence of regulatory intervention.

But in the other hand, what is the main implications to the policy makers? Should be banned or it can provoque good effects? (Whitney and Gaisford, 1999).

Chapter 3

Firm's Decision to Spy

"Access to secret intelligence is one of the more potent aphrodisiacs of power."

David Stafford, 1949 -

3.1 Introduction

We could start to describe our perspective of espionage by *Once upon a time*, such as any fictional story due to the blockbusters surrounding spy activities, as James Bond, Evelin Salt, or even in a more comic perspective, Johnny English. Although, the espionage actions affect the companies reality, and it is not a complex situation in the small or medium size companies, but in the largest companies that actuate in the different competitive industries. Cases such as Hilton Hotels & Resorts versus Starwood Hotels & Resorts Worldwide Inc., Mattel Inc. versus MGA Entertainment Inc. and Motorola Inc. versus Huawei Technologies Co. Ltd show us that the scandals and the spying activities are performed by those which are *too big to fail*[1].

The reality of espionage is transversal to any particular activity. The demand for a competitive advantage or even the search to increase it prompt the companies to overcome the ethical and cultural boundaries, incurring in spy actions. However, as we said before, the economic rationality shows us that this operation can be healthy in the competitive context (Solan and Yariv, 2004; Vashisth and Kumar, 2013).The spy actions of Bayerische Motoren Werke AG (BMW AG) to Autolib, the hiring of former General Motors Corporations employees by Volkswagen Group in order to share particular secrets of the production operations of the rival and the disclosed confidential information by the

[1]http://exame.abril.com.br/negocios/10-casos-de-espionagem-industrial/

designer of Gillette (Procter and Gamble Company Brand) to its peers, Warner-Lambert (Pfizer Inc. acquired company), Socit BIC S.A and American Safety Razor Company demonstrate that espionage implies an economic rationality between the costs and the benefits of such operation, that could rebalance the competition and reduce the industrys costs[2].

3.2 The Model

Let start to consider a duopoly market, where two enterprises, based on a similarity in the costs and in homogeneous products that offered, share the market equally (Whitney and Gaisford, 1999). The spy cases of Procter & Gamble Company versus Unilever Group, Coca-Cola Company versus PespsiCo Inc. and Airbus SAS versus Boeing Company empirically state that in the context of oligopolistic industries (specifically duopoly) with larger entry barriers and high levels of R&D push the companies to use any mean to create a competitive advantage. In our first perspective, we will consider a specific company, S, acting in a duopoly market which has the option to spy its rival, R. The tracing of such spying strategy only happens due to a harmful situation that company S faces, *i.e.*, S recognizes that, in a normal situation and without any structural shift in demand, the marginal production costs, c, are equal between them and constant which implies an equal partition of the market. But *ex ante*, S knows that R possesses a cost adavantage that allow this company to produce to lower costs, which compromises this situation.

On the consumers perspective, their preferences and taste assume a linear relation between the markets price, P, and the total quantity available, in the market, given by the sum of outputs of both competitors (Whitney and Gaisford, 1999; Azevedo et al., 2016).

$$P = a - b(Q_S + Q_R) \tag{3.1}$$

Where a represents the constant, b the slope of the function while Q_S and Q_R shows the total amount produced by S and R.

As we mentioned before, R suffered an exogenous positive improvement that affects the balance the market, and specifically the production costs. This shock concentrates in an improvement of its technology, the production methods or even the strategic plans of R, that enables this company to be *one step ahead of the competition*, and therefore, produce to a lower marginal cost, $c-\delta$. The marginal cost reduction, δ, translates a single, discrete and individual advantage that allow company R to collect direct and strategic benefits from this market, through a larger level of and a larger set of clients. In opposition, S faces a harmful situation, with a deterioration of its profit's level.

[2]https://www.bloomberg.com/news/photo-essays/2011-09-20/famous-cases-of-corporate-espionage

Taking into consideration the new cost structure of the company and since the market does not record any other exogenous shift in demand, the profit and the total output amount produced by both companies change, being the company R in better position that company S, with a higher profit to R. The market also improves with lower price and larger consumer surplus.

Symmetric Costs		Cost Advantage of R
$c_R = c$	$>$	$c_R = c - \delta$
$c_S = c$	$=$	$c_S = c$
$Q_S = \dfrac{a-c}{3b}$	$>$	$Q_S = \dfrac{a-c-\delta}{3b}$
$Q_R = \dfrac{a-c}{3b}$	$<$	$Q_R = \dfrac{a-c+2\delta}{3b}$
$\pi_S = \dfrac{(a-c)^2}{9b}$	$>$	$\pi_S = \dfrac{(a-c-\delta)^2}{9b}$
$\pi_R = \dfrac{(a-c)^2}{9b}$	$<$	$\pi_R = \dfrac{(a-c+2\delta)^2}{9b}$
$P = \dfrac{a+2c}{3}$	$>$	$P = \dfrac{a+2c-\delta}{3}$

Table 3.1: Productivity and Profitability Levels of the Market for a symmetric market structure of the cost, c, and for an advantage of R.

These two described states elucidate the market situation that occurs exogenously, *i.e.*, S can not prevent anything to happen and it only can ease the effects of such improvement of R's production. The possible action that can commit is espionage once that the current situation, is harmful to its level of profitability. Thus, S needs to compete equally and be able to *entry* in the market. Managers and administration plan to consider spy activities with the goal of understanding what is the main secret advantage of R and implemented in the productive process.

In this first model, R has a *passive attitude* because it is assumed that it can not do anything to block the spy attacks of S. On the other hand, S has knowledge about the asynchronous process of espionage and the inlay of Rival's advantage in their productive process, *i.e.*S knows that exists three distinct periods. First, the conduction of espionage activities, followed by the disclosure of the results of such actions. Lastly, the Cournot Duopoly Game performed by both companies. The knowledge of the order and the different steps of the process allow S to antecipate the subsequent play of the *Duopoly Game* when invests in espionage. Therefore, it allows the model to be calculated backwards (Whitney and Gaisford, 1999).

Figure 3.1: The Time Line of the Events, adapted from Whitney and Gaisford (1999)

The success or the failure of the spying activities are dependent by the parameter p, know as the *penetration rate* as in Whitney and Gaisford (1999). The penetration rate measures the quality of the spy attempts, or the probability of S incorporates the positive advantage in the productive process. In this way, p translates the success of spy actions of S to acquire the advantage of R, whereas $1 - p$ captures the failure of their actions. In case of success, the company S acquire the vantage of the company R and apply it in the productive process, which leads to a fall in the marginal cost to the same level of company R, $c - \delta$. In this case, both companies share the market equally again, in terms of quantity and profit, *i.e.*, they become symmetric again. With a successful attempt of espionage activity, the enterprise S will be able to recover or earn an extra profit flow, provided form the higher produced amount. The penetration rate also can also determine the total of information acquired by the production process of R.

In case of failure, S remains producing at a marginal cost of c and the company R produces to a better situation, $c - \delta$. It is relevant also to refer that, in this we do not consider any cost resulting from the failure of the spying attempt of the company S, in what concerns to public embarrassment or other kind of reputation costs. We assume that in the case of failure, company R knows that it was spied but it does not know who was responsible for this. The cyber attack in 2006 to a set of 70 companies, governments and non-profit organizations that some companies traced the possibility of being conducted by Chinese authorities can sustain this assumption[3].

In Table 3.2 we present both states provided by the failure or the sucess of spy actions, based on a Cournot Duopoly Game. As it is possible to see, the sucess of the spy actions and the inlay of the R's benefic features in S's production allows S to decrease its costs and simetrically split the market with R, in what concerns to the output and the level of profit. In case of failure, S and R split the market based in the cost difference with a advantage position to R, being its the costs of both companies intact, as it is shown in Table 3.2.

The assumption that $a - c - \delta$ is strictly positive allow us to realize that S will produce

[3]https://www.bloomberg.com/news/photo-essays/2011-09-20/famous-cases-of-corporate-espionage

in each unfavourable situation, even with a significant cost's difference between R and S (Whitney and Gaisford, 1999).

The swift between both the cost's structure of S between the two states translates into a improvement of S's output , $\frac{2\delta}{3b}$, and a profit disparity of $\frac{4\delta(a-c)}{9b}$. In the case of R, the production is reduced in $\frac{\delta}{3b}$ and the profit fell $\frac{2\delta(a-c+\frac{3}{2})\delta}{9b}$.

	Unsuccessful Spy Action	Success Spy Action	Espionage Impact
Occurrence's Probability	$1-p$	p	
Output Produced by S	$\frac{a-c-\delta}{3b}$	$\frac{a-c+\delta}{3b}$	$+\frac{2\delta}{3b}$
Output Produced by R	$\frac{a-c+2\delta}{3b}$		$-\frac{\delta}{3b}$
Profit for S	$\frac{(a-c-\delta)^2}{9b}$	$\frac{(a-c+\delta)^2}{9b}$	$+\frac{4\delta(a-c)}{9b}$
Profit for R	$\frac{(a-c+2\delta)^2}{9b}$		$-\frac{2\delta(a-c+\frac{3}{2})\delta}{9b}$

Table 3.2: State Contingent Cournot-Nash Duopoly Outcomes for each state of Espionage Activities' results

3.2.1 Optimal Spy Equilibrium

Let us consider that the profit flows of both companies evolve randomly, being affected by X as a multiplicative exogenous shock that follows a *Geometric Brownian Motion* (gBm), exemplified by :

$$dX(t) = \alpha X(t)dt + \sigma X(t)dz \tag{3.2}$$

In which α corresponds to the drift rate, *i.e.*, the risk neutral rate and σ translates the instantaneous profit volatility and dz the standard increment of the *Weiner* Process.

Taking into consideration the value of the company as the total profit flows generated in the future, if the company is able to support a scenario where the marginal costs are larger than its peer, R, the value of the company is given the following expression (Azevedo et al., 2016).

$$v(X) = \int_0^\infty \frac{(a-c-\delta)^2}{9b} X e^{-(r-\alpha)t} dt = \frac{(a-c-\delta)^2}{9b} \frac{X}{r-\alpha} \tag{3.3}$$

However, the decision of the company to incur in espionage activities alters the future estimations of S. In the case of a favourable decision to espionage activities, the value of the enterprise S will be conditional to the success or failure of such activities. Based on the risk neutral profile of S, the expected value of the company is given by the future profit flows, weighted by the state contingent of the spy actions.

$$\begin{aligned} V(X) &= (1-p)\int_0^{\infty}\frac{(a-c-\delta)^2}{9b}Xe^{-(r-\alpha)t}dt + p\int_0^{\infty}\frac{(a-c+\delta)^2}{9b}Xe^{-(r-\alpha)t}dt \\ &= (1-p)\frac{(a-c-\delta)^2}{9b}\frac{X}{r-\alpha} + p\frac{(a-c+\delta)^2}{9b}\frac{X}{r-\alpha} \end{aligned} \tag{3.4}$$

Where p is the *penetration rate*, that determines the success of the Espionage activities. It also should be noted that the penetration rate, p, drives the probability of success of such actions. However, the decision of the company to incur in spy actions comes with a price. The Espionage Cost, will be dependent on the quality or intensity of the spy actions powered by S.

$$K(p) = \frac{p}{1-p}z \tag{3.5}$$

The Equation (3.5) defines the structure of espionage costs of S, where p corresponds to the penetration rate and the z will be a scale parameter of these costs. Also, Equation (3.5) assumes a *one shot cost structure*, in other words, the company pays a specific amount in the beginning of the process and it does not have any other financial burden with the activity. The hiring of the services of detective's agencies, as it happens in the Oracle's espionage attempt to Microsoft's suppliers and collaborators exemplifies this assumption[4]. But, specifically, as we said before, the dependency of the spy costs of its outcome, *i.e.*, of the level of information that could get from its peer require a specific behaviour of the costs. Along with the continuous behaviour and the twice differentiable condition, we assume that cost of espionage will be unbearable when the company tries to ensure the highest available quality or all process of R, *i.e.*, a penetration rate equal to 1. In other words, if the company would like to insure the granted success of the espionage activities, the subsequent cost would be unsupportable. On the other hand, when the company does not take any kind of information or the p is null , the company will not support any spy cost. In marginal terms, we also assume that the additional rise of the cost will be more than proportional to the additional rise of the penetration rate, *i.e.*, the marginal cost of the spying will increase more than proportional the probability of penetration in the company R[5]. Although, this condition is also indirectly determined in

[4]https://www.bloomberg.com/news/photo-essays/2011-09-20/famous-cases-of-corporate-espionage

[5]Whitney and Gaisford (1999) also exemplify this behaviour, stating that the positive behaviour of the average cost of spying, $\frac{K(p)-K(0)}{p}$ always increase with the rise of the penetration rate.

the continuous behaviour assumed before.

$$\lim_{p \to 1} K(p) = +\infty \tag{3.6}$$

$$\lim_{p \to 0} K(p) = 0 \tag{3.7}$$

$$\frac{\partial K(p)}{\partial p} > 0 \quad , \quad \frac{\partial^2 K(p)}{\partial p^2} > 0 \tag{3.8}$$

Established the cost of espionage and the expected value of S, conditional to the success of the espionage activities , it is possible to formalize the investment problem of the company S, *i.e.*, the company S is facing a decision to incur in espionage activities, based on its profitability and its costs. In order to solve this problem, we adapt the model of Huisman and Kort (2015) that takes into consideration the optimal penetration rate and the optimal trigger to initiate the spy operations.

$$V(X) = \tag{3.9}$$
$$= \max_{t \geq 0, 0 \leq p \leq 1} E\left(\int_{t=T}^{\infty}\left((1-p)\frac{(a-c-\delta)^2}{9b} + p\frac{(a-c+\delta)^2}{9b}\right) X e^{-(r-\alpha)t} - \frac{p}{1-p} z e^{-rT} | X(0) = X\right)$$

Taking into consideration this decision, T expresses the time horizon that the decision will be undertaken, while p establishes the penetration rate in the productive system of the company R. However, the decision of the company is dependent on the total information available at time 0.

In order to solve this problem, we need to split the solution in two steps. The first consist in solving the optimum level of penetration rate, based on any level of the state variable (X). The corresponding p to any X is given by solving:

$$\max_{0 \leq p \leq 1} E\left(\int_{t=0}^{\infty}\left((1-p)\frac{(a-c-\delta)^2}{9b} + p\frac{(a-c+\delta)^2}{9b}\right) X e^{-(r-\alpha)t} - \frac{p}{1-p} z | X(0) = X\right) \tag{3.10}$$

Which gives,

$$p^* = 1 - \frac{3}{2}\sqrt{\frac{zb(r-\alpha)}{X\delta(a-c)}} \tag{3.11}$$

Equation (3.11) expresses the optimal penetration rate, based on the costs of spy actions, for any level of X. The level of optimum level of penetration or the probability translates the equality between the marginal benefit of increasing the intensification/penetration rate of the spy attempts of S to R' activities and the marginal cost to obtain it.

It is also should be noted that the optimum penetration rate is translate, in numerical terms, in the equality between the marginal cost of spy activities and the S's profit disparity the two contingent-states of espionage's results[6].

From Equation (3.11), we are able to identify the positive relation between the penetration rate and the value of the trigger, the cost advantage of company R and the riskless growth rate. Thus, as the cost's difference increase or R's cost improvement increases, the marginal benefit of the spy actions rise, which boost the intention of the S to a larger knowledge about the R's production process. With a larger price able to pay with the non-existence of supply (a), as well as the better perspectives about the future of the company, that translates in a larger riskless growth rate, greater will be the intensity or the quality of the spy attacks of S. Thus, the rise of this parameters will lead to a more favourable decision in what concerns to the use of espionage actions. In opposition, higher levels of costs, whether connected to spy actions or to production, higher sensibility of the costumers to potential drifts in the price, as well as higher interest rate, or opportunity cost to incur in other alternatives lead to lower levels of optimal penetration rates. Whitney and Gaisford (1999) addressed the spy cost as an important factor to the occurrence of such actions, due to the role performed in the efficiency for the company. The low cost of intelligence operations after the end of *Cold War*, as weel as the excess of resources in this area of led to a greater incentive of these activities (which in our model leads to a larger penetration rate). Therefore, the higher optimal outcome provided by the spy actions, p^*, is demanded when embodies larger values of X, a, δ, α and lower values of z, b, r and c[7].

Based on the benefits and the costs of espionage activities and its influence in the value of S, this company will exercise the option to spy considering the indirect and direct costs. Assuming $F(X)$ as the value of the option to espionage and $X^\star$ as the optimal exercising value (trigger), the value of espionage will be given, after investment, by solving the following ordinary differential equation (ODE):

$$\frac{1}{2}\sigma^2 X^2 F''(X) + \alpha X F'(X) - rF(X) + \frac{(a-c-\delta)^2}{9b} X = 0 \tag{3.12}$$

Taking into consideration Dixit and Pindyck (1994), the general solution must take the form of:

$$F(X) = AX^\beta + \frac{(a-c-\delta)^2}{9b}\frac{X}{r-\alpha} \tag{3.13}$$

In order to choose the optimal investment decision, the company must satisfy the

[6]Taking into consideration our model and the behaviour of each variable, the penetration rate will be always positive due to the lower value of the marginal cost of espionage in relation to its benefit when the penetration rate is null (Whitney and Gaisford, 1999). It is possible to see in the Appendix A

[7]In this study, we take into assumption that $X(0) < X^*$, stating that it is not optimal to invest in the first moment. Only when the company reaches X^*, the company S will invest. In this way, the optimal investment time equals the first time that the stochastic process X, starting at $X(0)$ at time zero, reaches the level X^*.

appropriate boundary conditions, given by the following equations,

$$\lim_{X \to 0} F(X) = 0 \tag{3.14}$$

$$\lim_{X \to X^*} F(X) = V(X) - K(z,p) \tag{3.15}$$

$$\lim_{X \to X^*} \frac{\partial F(X)}{\partial X} = \frac{\partial V(X)}{\partial X} \tag{3.16}$$

The first condition, named as *absorbing barrier condition*, establishes that the value of the company, as the trigger is closing to zero, the value of the option is also worthless. The second and the third condition, known as *value matching condition* and *smooth past condition*, respectively, explain us that the Value of the option to spy equals the present value of the future profit flows of S, conditional to the probability of espionage the company R, net from the implicit costs of this action when the trigger is closing from the optimum value. Although, the proximity will be smooth, *i.e.*, the metamorphosis of the value of the option to the net present value of the profit flows happen continuously. This situation is mathematically interpreted by the equality between both value functions derivatives. Remitting for espionage environment, Equation (3.15) elucidates that the net benefit of the spy actions n the total amount of the future profit flows of S will be equal to the value S in a unfavourable situation with an option to incur in such activities, at the X^*. However, as we said before, this equality results from a process of approximation of the value of both states, as it is stated in Equation (3.16).

X^* denotes the optimal moment to incur in espionage, This optimum value of Equation (3.2) shows us that the S is indifferent at this point between investing or not in the spy actions. The corresponding optimal penetration rate is given by $p^*(X^*)$. To levels of X higher than X^*, the company is facing the stopping region, where it is optimum to invest immediately. In opposite situation, the scenario where the value of X is lower to X^*, the profit is still too low to sustain the espionage actions. Therefore, the company should wait to invest, being present in the continuation region (Huisman and Kort, 2015). Taking into consideration the Equation (3.12), Equation (3.14), Equation (3.15), Equation (3.16) , we are able to solve the second step of the problem, the value of X^*. The value of the S, taking into consideration the vlaue of the option to invest in espionage operations is given by:

$$F(X) = \begin{cases} AX^{\beta} + \dfrac{(a-c-\delta)^2}{9b}\dfrac{X}{r-\alpha} \text{ if } X < X^* \\ \dfrac{(a-c+\delta)^2}{9b}\dfrac{X}{r-\alpha} + z - \dfrac{2}{3}\sqrt{\dfrac{Xz\delta}{b(r-\alpha)}}(\sqrt{a-c} - \sqrt{c-1}) \text{ if } X \geq X^* \end{cases} \tag{3.17}$$

Where,

$$\beta = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + 2\frac{r}{\sigma^2}} \tag{3.18}$$

$$A = z\frac{\left(\frac{4}{9}\right)^2 \left(\frac{bz(r-\alpha)\beta^2}{\delta(a-c)(\beta-1)^2}\right)^{-\beta}}{(\beta-1)^2} \tag{3.19}$$

To those parameters, the value of the optimal trigger X^* and the specific $p^*(X^*)$ is equivalent to:

$$X^* = \frac{9bz(r-\alpha)}{4\delta(a-c)}\frac{\beta^2}{(\beta-1)^2} \tag{3.20}$$

$$p^*(X^*) = \frac{1}{\beta} \tag{3.21}$$

It is possible to identify the resemblances between the optimal penetration rate at optimal trigger and the optimal output value of our model, given by Equation (3.20) and Equation (3.21), with the similar parameters on the study of Huisman and Kort (2015). In Equation (3.20), it is also useful to identify two parts of the general component, $\frac{9bz(r-\alpha)}{4\delta(a-c)}$, and a risk factor, $\frac{\beta^2}{(\beta-1)^2}$.

Considering that $\frac{\partial\beta}{\partial\sigma} < 0$, $\frac{\partial\beta}{\partial\alpha} < 0$ and $\frac{\partial\beta}{\partial r} > 0$, we develop a sensitivity analysis in order to understand the marginal effect of different parameters (Dixit and Pindyck, 1994). Based on the value of X^* and $p^*(X^*)$, we assume that:

$$\frac{\partial X^*}{\partial\beta} = -\frac{9bz(r-\alpha)}{2\delta(a-c)}\frac{\beta}{(\beta-1)^2} < 0 \tag{3.22}$$

$$\frac{\partial p^*(X^*)}{\partial\beta} = -\frac{1}{\beta^2} < 0 \tag{3.23}$$

Through the previous results, and as it is announced in the Real Options Approach, the rise in the uncertainty, σ, results in a larger penetration rate as well as a larger optimal moment. In other words, the higher uncertainty surrounding the market of both companies implies that the firm invest later but for a larger penetration rate. Also, the larger volatility will also be granted a higher intesity of spy actions of S in R, as it happens in Huisman and Kort (2015) and Dixit and Pindyck (1994), *i.e.*, the company opts to a larger certainty in the espionage output in times of higher risk, as well as a larger amount of information.

Thus, the large level of uncertainty that is installed in the market can define some concepts of the industry. One of these is the expectations of S. With a increase of the uncertainty in the market, S might search a larger amount of depth of the information provided by the spy actions, which is translated with a larger p^*.

Also, the rivalry between companies can be theoretically analysed. Whitney and Gaisford (1999) affirmed that espionage is influenced, in practical terms, for the *struggle* between the enterprises in the industry. However, in theoretical terms, the greater conflict between companies or strategic quarrels might be synonym of the larger risk or uncertainty in the future, once that S has a higher chance of being a target of harmful situations. In this way, the rise of the conflict between S and R might induce in a larger volatility, σ, which might bring a higher disposition of S to obtain a higher amount of information through espionage operations. But, this larger certainty or intensity will be postponed in relation to the optimal timing.

The rise of uncertainty that leads to a larger $p^*(X^*)$ also highlights the boost of the cost of espionage. Methodologically, the cost structure of our model justify this relation. According with economic intuition, the rise of $p^*(X^*)$ and consequent rise of K can elucidates the quality improvement of the instruments used or even the higher demand for the means used in the spy attempts[8].

Empirically, it can be shown this effect once industries where the risk and the uncertainty surrounding the structure changes in the future are more vulnerable to potential successful spy attempts of its competitors. The high-tech industry is a real example of this situation, where potential innovations in the future change the market's structure and the peers that cannot have a R&D so developed opted for spy actions.

As we see before, the uncertainty also positively conditionates the optimal timing to incur in espionage. We can stablish two of opposite effects when S tries to incur in spy actions. The company can be interested in spying R quickly, in order to decrease the time horizon that will be in disadvantage in relation to R, and also more vulnerable to potential threats that jeopardize its position. Although, the swift spy attempt comes with a lower level of quality or intensity (the lower X^* decreases $p^*(X^*)$). By the other hand, S can opt for different strategy, *i.e.*, S can wait more time to spy R and bear out a longer period in disadvantage and invest in a larger attack (a larger X^* implies a greater $p^*(X^*)$). Based on larger levels of uncertainty, S becomes more reluctant to the first strategy and tolerates a higher financial pressure (due to the a longer period in disadvantage), but when incur in spy actions, the level obtained of information or the intensity of spy operations will be higher.

[8]It is possible to identify this two effects separately. A larger intensity or quality inlay a greater $p^*(X^*)$, but considering that it is not possible to higher quality, the company can opt for a larger amount of tools, which in both circumstances, increase the level of information obtained and also the cost of these operations.

The optimal timing to incur in spy activities is also influenced by the cost structure of S. As the cost increase, either c or z, the optimal time to start the espionage activities is postponed, which translates a greater reluctance to incur in spy activities or own a superior level of expected profits to bear the costs of this operations. This inference can justify the relative cost of innovation, *i.e.*, when the cost of espionage is too high, it loses the cost's advantage comparing to innovation, which leads the company to incur in, *e.g.*, R&D activities.

Related with the costs, the cost advantage also deserves attention. The inverse relation between the trigger and the parameter, δ, shows that, as long as the disparity between the costs of both companies is significant larger, S should invest in spying activities in a shorter period of time, in order to sustain its activity. It can also be considered indirect effects of the significant discrepancy among companies. As it the model's conception is based on Cournot Duopoly Game, the larger difference in the costs determines a lower market's share for S, due to the larger production cost that company charges. This higher cost, comparing with the R, decrease the consumer's sentiment to change if any external act occur. In this way, S hastens the spy actions against R.

However, the model shows an effect in the time that company decides to incur in espionage activities, but it does not do any reference to the optimal penetration rate. The non-inclusion of any consequence of the company conditional to the result of the spy attempts of S might explain this effect, *i.e.*, whichever the result of the spy actions or the level of information withdrawn by R, S will not be *condemned* for its practices. This non-responsibility of S for its actions leads to a concentration of the enterprise's decision in the moment which incur in such actions, which leads to a direct influence of all factors in X^*. In this way, the level of information obtained for R, $p^*(X^*)$, only depends the market's environment and the macroeconomic conditions. In this way, no matter what it will result, when the company decides to incur in spy actions,S has no problem of accepting the consequences of espionage attempts.

$$\frac{\partial X^*}{\partial z} = \frac{9b(r-\alpha)\beta^2}{4\delta(a-c)\beta^2} > 0 \tag{3.24}$$

$$\frac{\partial X^*}{\partial c} = \frac{9bz(r-\alpha)\beta^2}{4\delta(a-c)^2\beta} > 0 \tag{3.25}$$

$$\frac{\partial X^*}{\partial \delta} = -\frac{9bz(r-\alpha)\beta^2}{4\delta^2(a-c)\beta^2} < 0 \tag{3.26}$$

3.3 Numerical Example

The company S and R share a specific market, where R has a significant cost advantage comparing to S, 10%. In order to know how R possesses a lower marginal production cost, S is considering to incur into espionage operations. The successful attempt implies a reduction of the production costs to S because it embeds R's production processes into S's production. However, such activities have a cost, that, in terms of scale, are equal to the marginal cost of production. Also, the demand in this specific market is not very sensitive to price shifts. It also should be noted that the company wants to reduce the losses that this cost advantage is bringing to them and balance the market with R. The value of the different parameters is present in the following table:

Parameters	Value
a	10
b	2
r	0.04
α	0.02
σ	0.3
c	6
δ	0.6
z	6

Table 3.3: Numerical Assumptions of the Different Parameters

Based on the previous model equations, we are able to identify the Optimal Trigger and the Optimal Penetration Rate:

Output	Value
X^*	5.26309
$p^*(X^*)$	0.79323

Table 3.4: Output Values for the parameters present in Table 3.3

Taking into consideration Table 3.3 and Table 3.4, the decision of making espionage actions will be optimally when the X^* is equal to 5.26309. Based on the analysis of the boundary conditions, presented in Equation (3.14), Equation (3.15) and Equation (3.16), the indifference moment for the company to decide if will incur in espionage activities happen when the optimal trigger reaches 5.26309. Below that, S is willing to bear out the market unfavourable position against R. Above, the company immediately opts for such actions to embed the productions costs of R in their productive product. However, this interpretation is only true if we connect this value with the optimal penetration rate. In this case, based on the parameters of volatility, risk free rate and growth rate, it is possible to realize that the company can successfully capture with a p equal to 79.323%, which possibilities a value of the company estimated in 280.334 monetary units, with a spy cost of 23.0189 monetary units. It is possible also to highlight the larger penetration rate implied in this optimal spy actions, with a larger level of spy intensity implied.

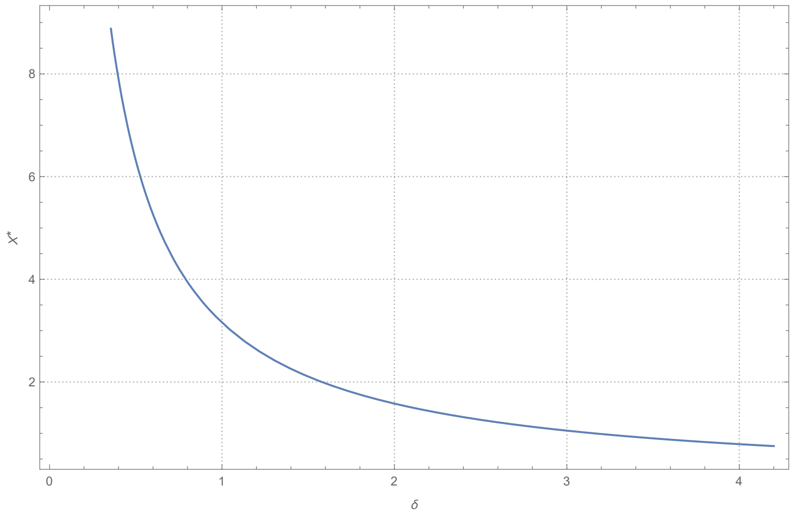

Figure 3.2: Evolution of the Optimum Trigger according to potential shifts of cost advantage, δ

As we said before, the rise in the cost's discrepancy among companies anticipates the decision of S to incur in espionage activities. An cost advantage of 70% for company R, as it is described in Figure 3.2 with a δ of 4.2, demonstrate a lower level of the profits for S. The same situation does not happen for an advantage of 10% (δ equals to 0.6), that demand a significant amount of profits to sustain the espionage activities. As we see in the analytical analysis, the optimal timing to spy are positive influenced by the operational costs, as well as the costs of espionage. It is possible to see the relation in Figure 3.3 and 3.4. In both figures, it is possible to see that as c and z increase, the optimal time to incur in espionage is delayed. However, the influence of costs of espionage is larger when we consider low levels of production and spy costs, and the opposite relation is observed to greater levels of costs.

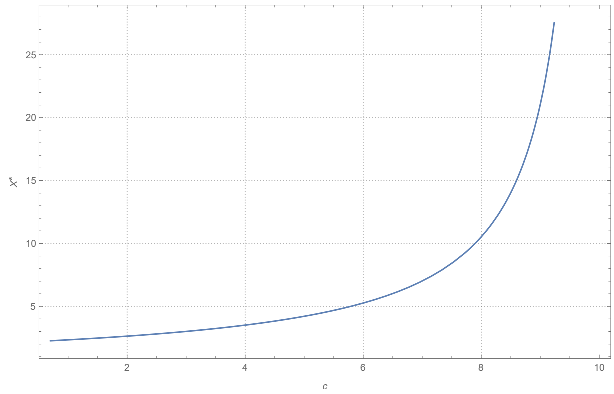

Figure 3.3: Evolution of the Optimum Trigger according to potential shifts of Production Costs, c

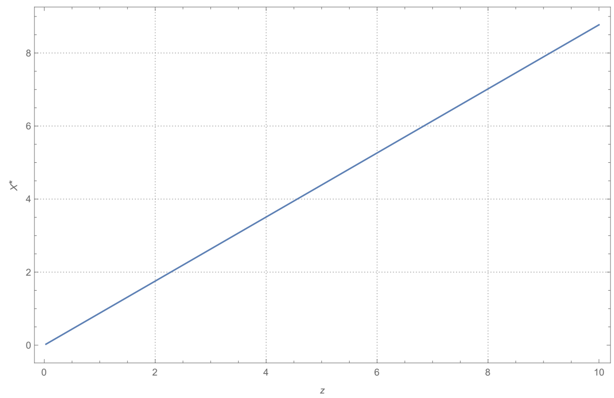

Figure 3.4: Evolution of the Optimum Trigger according to potential shifts of costs of espionage, z

Chapter 4

Society's Decision to Spy

"The object of the Government
is the Welfare of the people"

Theodore Roosevelt, 1858-1919

4.1 Introduction of the Regulator's Role

In the last section, we designed an efficient model that establishes the optimal time to spy by the company S in its rival, R, that possesses a cost advantage due to a favourable organization or even a technological advance that S knows *ex ante*. In spite of such decision being efficient to the company, it is possible that the general society is better off with the occurrence of the spy actions? Is it possible that the these profits flow transference to the company R induces a better aggregate position to the costumers and to the producers?

This economic welfare for the consumers and producers presented in the market is fully maximized in a competitive environment, as it is characterized by the perfect market competition (Fisher, 2007). The incentives provided to innovate and decrease the production and distribution costs to the possible lowest price guarantee the equality between the marginal social benefits and costs (Fisher, 2007). However, the scope of the normal profits under important identified circumstances are not possible to achieve (Fisher, 2007). The non-reflection of the marginal social costs in the marginal production costs, the significant disparity between the individual and the social marginal benefits, as well as the lack of competition and the absence of externalities might contributes to the society's conditions degradation. In the present model, the best interest of the society might have been set aside once the entry barriers and the presence of only two companies in the market does not accommodate a high level of competition. The non-existence of significant externalities also support the non-perfect environment.

Thus, when the competitive choices does not match the society's best interests or the market's efficiency, the regulator should improve the performance of the industry (Fisher, 2007). This regulator, that might be acted by the Government, ensures the efficient use of the resources and the maximization of the social welfare. In this way, the government should promote the best costumers' and producers' satisfaction, *i.e.*, the resource's allocation that ensures the largest social welfare, that could not improve without the deterioration of someone. The mitigation of the distribution inequality and the macroeconomic stabilization are also a priority (Musgrave, 1959).

When the decision of the government is preferable in relation to the singular decision of the agents presented in the market, the consequences in the welfare of any decision are the primary objective to determine the investment size and timing (Huisman and Kort, 2015; Fisher, 2007). The welfare of the society constitutes the net gain for the suppliers and consumers of producing a specific amount of output. This concept can be captured in a specific market by the total or social surplus, $W(X)$, that represent the sum of the consumer surplus, $CS(X)$, and the producer surplus, $PS(X)$, (Cullis et al., 2009).

In respect to consumer's role in the market, it is priority of the Government to improve the consumer surplus in the market until the largest level of efficiency. The following Equation presents the instantaneous value of the consumer surplus.

$$CS = \int_{P(Q_R,Q_S)}^{a} \frac{a}{b} - \frac{P}{b} dP = \frac{1}{2} b(Q_R + Q_S) \tag{4.1}$$

According to Marshall (1920), one of the first to study the role of the government in the market's efficiency, establishes that consumers surplus comprehends the discrepancy between the price that a consumer is able to pay and the price that actually paid. This difference between the marginal benefits of the consumers and the market's price paid, conditional to a fixed level of income, positive evaluates with the lower cost structure of R and S.

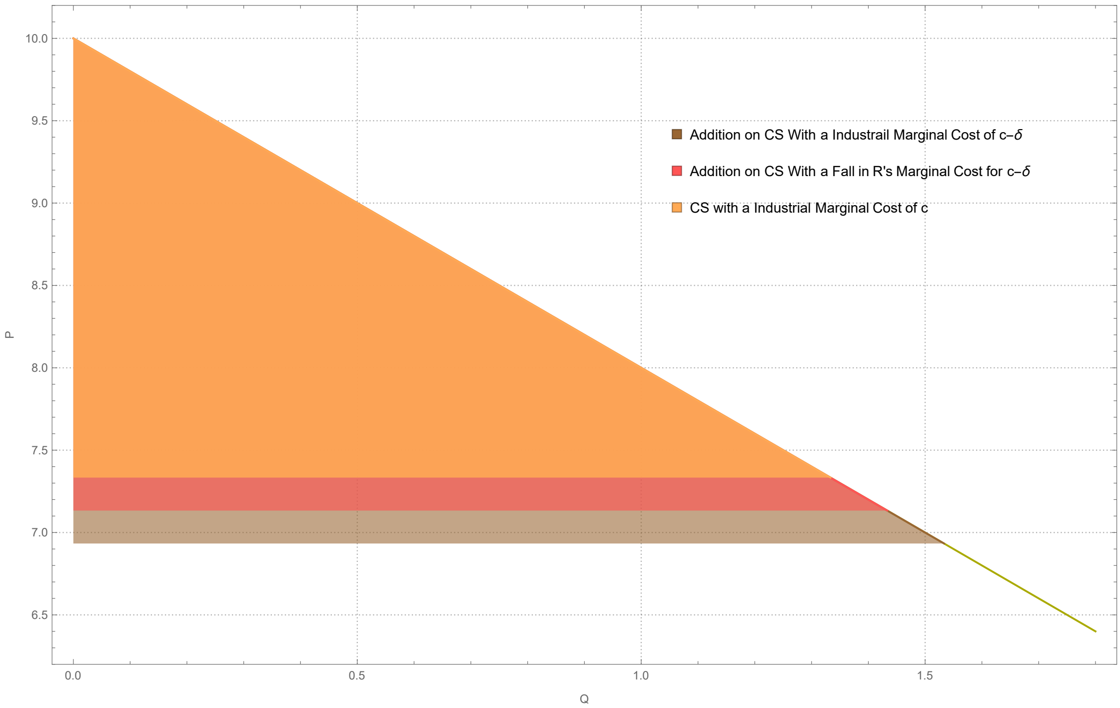

Figure 4.1: Evolution of Consumer Surplus based on the assumptions of section 3.3, according with the Swifts in the Marginal Costs of R and S

The improvement in the efficiency of the production of company R, that led to the margin production cost of δ , allowed that a marginal rise of the consumer surplus of $\frac{\delta(4a-4c+\delta)}{18b}$ [1]. The enhance of the disparity between the marginal benefits for the consumer and the actual cost they paid for a unit of output is result from the interaction of both companies in the market that allows a larger produced output and a lower price (Fisher, 2007).

The enhancement of the consumers welfare is even greater when S successfully spy R. In this state, the surplus measured by what consumers is able to pay and what actually pays rises $\frac{\delta(2a-2c+\frac{3}{2}\delta)}{9b}$ from the state where S presents larger production costs. From a initial situation, where both present a marginal cost of c, the consumers surplus registered an improvement of $\frac{\delta(4a-4c+2\delta)}{9b}$.

As previously, the rise in the welfare of the consumers is only possible from a reduction of the marginal production cost, that consequently (through a Cournot Duopoly interaction), allow a rise in the output created by both companies and a lower market price. As it is present in Table 3.2, the success of espionage operations for S enhances the industry's output in $\frac{\delta}{3b}$ and decreases the market price from $\frac{a+2c-\delta}{3}$ to $\frac{a+2c-2\delta}{3}$. In theoretical terms, the welfare of the consumers improves *via* two major effects, the *income effect* and the *substitution effect* (Cullis et al., 2009). The *income effect* shows that

[1]For deeper analysis, see section B

espionage activities enable consumers to pay a lower price which rises the real income that clients detains. On other hand, the lower price guarantees a substitution of the consumer, in deterioration to those with larger prices, that translates in the *substitution effect*.

The welfare of the consumer is influenced by the success or failure of espionage operations and Equation 4.1 needs to capture this effect. As it happens in Equation (3.4), the CS demonstrates the expected outcome of spy actions in the disparity between the benefits and the actual cost for the consumers. In this approach, as it happen before, the *multiplicate shock* will affect the instantaneous consumer surplus in the market.

$$\begin{aligned} CS(X) &= E\left(p\int_{t=0}^{\infty}\frac{2(a-c+\delta)^2}{9b}Xe^{-(r-\alpha)t}dt+(1-p)\int_{t=0}^{\infty}\frac{(2a-2c+\delta)^2}{18b}Xe^{-(r-\alpha)t}dt|X(0)=X\right)\\ &= \frac{X}{r-\alpha}\left((1-p)\frac{(2a-2c+\delta)^2}{18b}+p\frac{2(a-c+\delta)^2}{9b}\right) \end{aligned} \tag{4.2}$$

The social welfare also integrate the *other side of the market*, the producers. The difference between the price charged by the market for the created output and the marginal cost of its production conceptualize the producers surplus (Fisher, 2007). As it happen in Huisman and Kort (2015), the value of the welfare of the suppliers equalizes the total amount of future profit flows, *i.e.*,the expected value of R and S.

Thus, the gap between the price that producers received and the minimum amount that they require to produce is conditional to the espionage outcome of the activities performed by S in the value of both companies, as it happen in the value of the consumer surplus (Cullis et al., 2009)[2]. The value of both companies, as it happen in the last chapter for S, are affected by the *multiplicative industrial shock* that follows the movement described in Equation (3.2).

$$\begin{aligned} PS(X) &= \\ E &\left(\int_{t=T}^{\infty}\left((1-p)\left(\frac{(a-c-\delta)^2+(a-c+2\delta)^2)}{9b}\right)+p\frac{2(a-c+\delta)^2}{9b}\right)Xe^{-(r-\alpha)t}-\frac{p}{1-p}ze^{-rT}|X(0)=X\right)\\ = &\ \frac{X}{r-\alpha}\left(p\frac{2(a-c+\delta)^2}{9b}+(1-p)\left(\frac{(a-c-\delta)^2+(a-c+2\delta)^2}{9b}\right)\right) \end{aligned} \tag{4.3}$$

The bottom gain for the society of the market's dynamic that translates in the production of the optimal quantity can be represented by the sum of both excesses, consumer and producer surplus. In this way, the social welfare, $W(X)$, translates the difference between the marginal benefits and the costs added by an extra unit of output

[2]The value of S is previously calculated in Equation (3.4). However, the value of R is presented on the Appendix A, for further detail.

for the society for all the opportunities in the market (Fisher, 2007).

$$W(X) = CS(X) + PS(X)$$
$$= \frac{X}{r-\alpha}\left(p\left(\frac{2(a-c+\delta)^2}{9b}+\frac{2(a-c-\delta)^2}{9b}\right)+(1-p)\left(\frac{(a-c-\delta)^2}{9b}+\frac{(a-c+2\delta)^2}{9b}+\frac{(2a-2c+\delta)^2}{18b}\right)\right) \tag{4.4}$$

4.2 Optimal Society's Spy Equilibrium

The individual decision of S in relation to the occurrence of spy actions with the aim of embed the competitive cost advantage of R in the intern production takes into account the efficiency according to the cost structure of the company. Based on this decision, the optimal timing and the penetration rate that equalizes the marginal benefit and cost for the company S, as it is present in Equation (3.21) and Equation (3.20), translates into a gain for the society of:

$$W(X^*, p^*) = \frac{zb(8\beta(a-c)^2 + 8\delta(a-c)(1+\beta) + \delta^2(11\delta - 3))}{8\delta(a-c)(\beta-1)^2} \tag{4.5}$$

Although, as we mentioned in the beginning of this chapter, the non-existence of substantial competition in the market, that provides conditions to S reduce the unitary cost of production of production, *via economies of scale*, and the existence of entry barriers that jeopardize the reach of the equilibrium between marginal benefit and cost, rises the gap between the fulfilment of the social interests and the efficiency of R and S (Fisher, 2007). Combining these factors with the absence of externalities in the company's decision, the behaviour of other agents, as consumers and peers, lift the importance of the Government's intervention in the market, as social planner or regulator. With the aim of maximizing the social welfare of the market, the government decides to approve or not to condemn the espionage operations of S under the methodological conditions that based S's efficient decision on the previous chapter. Therefore, The social optimal timing to incur in espionage actions and the optimal intensity of such actions is given by[3]

$$X^{**} = \frac{18bz(r-\alpha)}{\delta(8a-8c-3\delta)}\frac{\beta^2}{(\beta-1)^2} \tag{4.6}$$

$$p^{**}(X^{**}) = p^*(X^*) = \frac{1}{\beta} \tag{4.7}$$

Based on the studies of Huisman and Kort (2015) and Equation (4.6) and Equation

[3]For detailed analysis of the calculation of the social optimal timing and penetration rate, see section B

(4.7), the comparision between the efficient social solutions demonstrate a bias, *i.e.*, the social optimal value of the penetration rate equalizes the efficient solution, Equation (3.21), which does not happen comparing with the related value in Huisman and Kort (2015). On the other hand, the social optimal timing to incur in espioange activities is larger than what is founded in Equation (3.20) on the S's efficient decision, contrary the equivalence proposed by Huisman and Kort (2015). Therefore, the government, in order to protect the best interests of the society, should defend an similar intensity of the espionage operations but later. For the regulator, it is only acceptable the activities of espionage with a larger postponement because the social optimal trigger is almost two times larger than the efficient optimal trigger for S.

With respect with the optimal timing for the government condemn the espionage decision of S, the social planner states a large timing to accept these actions, only achievable by mature or more developed industries. In this way, it is possible to perceive that the government decision is dependent on the *life cycle phase* of the company, accepting such actions when the company reaches a significant level of maturity or stability and reprimand them when the enterprise decides to spy in a earlier stage of the business cycle, either in the beginning of its activities or either in a later stage when firm is still small, but with a larger set of opportunities to grow.

Also, through the timing in which is socially optimal to espionage, it is apparent or pertinent the government protection of the production and innovation activities of small-size companies , or even *start-up projects*, due to the larger set of cash flows that is required to accept spy operations.

The acceptance of spy actions for developed industries or more mature can be theoretically justified by the break of the industrial *status quo*, *i.e.*,the espionage activities is seen as an incentive to the companies presented in the market to improve its production methods, or even expand to other areas. In other words, the acceptance of such actions might lead companies to improve constantly its methods because firms have the knowledge that cash flows stability might be compromised by espionage.

Comparing the optimal timing in firm's and society's decision, presented in Equation (3.20) and Equation (4.6), it is possible to conclude the equal effect of all parameters concerned with the preferences or marginal benefits of the consumers (a and b), the industry production and operation's Costs (c ,δ and z) and the uncertainty or vulnerability of the market (σ). It should be noted that the cost advantage, δ, present a more complex effect, with a higher influence on the timing with two opposite forces. Although in aggregate terms, the cost advantage holds the same effect as before.

The disparity between the optimal timing to incur in espionage for S and for the society shows a different approach to study the implications of spy activities in the society and in the economic performance. According to the section 2.4, the role or the effect of espionage does not generate consensus in the literature, existing authors like ,Whitney and Gaisford (1999), Cozzi (2001) and Solan and Yariv (2004) that evidence the benefits of espionage, in what concerns to a swift technological diffusion in the society, higher level of efficiency due to the lower cost of Information and better economic conditions provided by the transference of cost's advantage.

In opposition, Crane (2005), Sarangi et al. (2010) and **?** demonstrated that espionage activities might bring harmful repercussions to the society. The deterioration of the commercial interest to the population, the long-term injuries caused by the quick growth of this activity and the non-repercussion in welfare improvements for this activities are some reasons that justify this *"dark side of the espionage activities"*.

Chen (2016) also highlighted the ambiguous effect of espionage in the society, that depends on two antagonistic forces, the technological transfer and the cost reduction investment.

Particularly, according to this study, the implications of espionage in the society highlight the timing in which they happen, *i.e.*, the timing of these actions decides if the spy actions will benefit the Society or does not meet the social interests. This bilateral nature shows that espionage activities happen before the optimal timing for the society (Equation (4.6)), the repercussions of such activities decrease the welfare of the society. Contrarily, if spy attempts begin after or in the optimal timing, the welfare of producers and consumers are safeguarded. In this way, the role of corporate espionage in the economy does not assure a stable effect, which might obligate the government and the regulator to be monitor the market's structure or conditions. Thus, government should work side by side with *players* of the market to promote the competition, the enhance of the market's performance and the social welfare (Fisher, 2007).

With the equivalence of the firm's and society's decision for the optimal intensity or quality of espionage actions, powered by S, this critical value achieve even more comprehensive concept. Besides of translating the equality between the extra benefit and cost of a potential unit rise of spy actions for S, it also adds the similar state for the society. In other words, the same solution match the social marginal benefit with the social cost. According to Fisher (2007), when the market or the economy can reach this equivalence, it achieves the full-efficiency, once there is no incentive to switch the state of the market.

The efficiency stated by the social equilibrium enables the exhaustion of all the aggregate gains of espionage activities for the society, as well as a production to the lowest possible unitary cost (Fisher, 2007). Therefore, the optimal timing and the equilibrium penetration rate for the society granted a social welfare equal to:

$$W(X^{**}, p^{**}) = \frac{z\beta(8(a-c)^2 + 8\delta(a-c)(\beta+1) + \delta^2(11\beta-3))}{(8a-8c-3\delta)(\beta-1)^2} \tag{4.8}$$

As we stated before, the firm's decision to incur in espionage earlier than it is optimal to the society compromises the aggregate benefits of the market of such action. It is possible to see this effect on the value of social surplus with the optimal equilibrium of S's decision, provided by Equation (4.8) and for the government decision. If S decided to invest sooner in spy actions against R, as it is stated by the efficient optimal trigger, the value of the social welfare will be lower than it is expectable with the social optimal time. In this way, is incurs in a loss for the society. Based on the difference of the welfare of both states, we are able to estimate the loss of welfare provided by the gap between both decisions.

$$\begin{aligned} \Delta W &= W(X^*, p^*) - W(X^{**}, p^{**}) \\ &= -\frac{3(8z\beta^2(a-c)^2 + 8\delta(a-c)(\beta+1) + \delta^2(11\beta-3))}{8(a-c)(8a-8c-3\delta)(\beta-1)^2} > 0 \end{aligned} \tag{4.9}$$

As we can see in Equation (4.9), the difference in the social welfare between both equilibrium is negative, which translates the improvement for the society caused by the decision of the government. Thus, it demonstrates the priority for the regulator to postpone the occurrence of espionage activities by S in relation to the efficient solution, for the security of social interests. In other words, the government should promote larger efficiency in the market through the junction of the optimal timing of S's and society's decision to incur in spy actions.

Theoretically, the government might promote the efficiency in the market through the market's nationalization, the creation of a wide range of incentives or also through the active regulation of market's economic activity of the companies (Cullis et al., 2009). The nationalization of the markets imply a direct provision of the products or services by the state, as it happen in the majority of the public goods. The set of incentives constituted the primordial method of public intervention based in the imposition of taxes and subsidies that guarantee a substantial change in the marginal benefits acquired by the producers and consumers. The legislation concerned with the financial markets, the health-care activities and education are crucial examples that demonstrate the intervention of the government *via* state regulation of the market.

Methodologically, the social planner must create *"public vehicles"* that delay the optimal decision of the company, or anticipate the social timing of incurring in espionage. With this objective, we will introduce two different public means that guarantee the parallel satisfaction of the social and S's interests. The counter espionage financed by the state and the introduction of the consumer subsidy allow the backwardness of the firm's decision until the optimal timing for the society.

4.3 Possible Actions of the Policy Maker

4.3.1 Defence Tactics

In aggregate terms, the success of espionage activities translates a improvement in the economic and financial conditions of S and in the consumers. However, the occurrence of such activities harms the situation of R, since the profit flow generated by the company decreases abruptly, and consequently, the future projections of the value of the company also falls (Whitney and Gaisford, 1999). As this larger level of efficiency of S and consumer surplus might not respect the social interests, the regulator may intervene in the market in order to re-establish the R's advantage and delay the entry of espionage activities in the activity of S.

In order to protect the activity of R, that, in aggregate terms, delays the success of the espionage activities and promote the retardation of the efficient optimal timing of S, the government promotes the use of defence techniques of company R.

The possibility of R counter-espionage or defend its cost's advantage is recurrent in practice. The Google's announcement affirming that the company was victim of a cyber attack, located in China, that failed in the attempt of stop the theft of immaterial assets shows the the existence of firm's defence instruments[4].

However, the public assistance might be very difficult to observe, and it is more recurrent the focus on the attack, *i.e.*, the financing of espionage activities. In order to embed the defence tactics, q will translate the *interception rate*, *i.e.*, the level of success granted by the defence techniques implemented by R. The interception rate also can translate the probability of company R intercept the spy actions of S. A vigilance system in the company may be an example of an instrument to promote the safety of the enterprise's facilities, and achieve a specific level of q.

As it happen in the penetration rate, the interception rate given by a specific or a set of defence instruments will reach unbearable costs if the enterprise or the regulator desire to achieve a full level of interception, a q equal to 100%. In other words, a probability of being able of fully protect the assets of R will translate an effective cost extravagant to the government. In line with p, the marginal rise of the interception level of espionage activities for the spied will lead to a more than proportional rise of defence costs.

The conditions above elucidates the decision's problem of R and government to choose

[4]https://www.bloomberg.com/news/photo-essays/2011-09-20/famous-cases-of-corporate-espionage

an appropriate set of security instruments that give a specific level of q, lower than 1 and larger than 0.

The dynamics behind the existence of defence and attacking techniques in the *conflict* between R and S also deserves some attention. In what concerns to the success of both activites, it is assumed in the model, according with the empirical evidence that, the interception rate absorbs the effect of penetration level. In other words, of the defence company is able to intercept espionage activities, it is impossible for S to scape or continue to spy R.

But what justifies R being willing to do such activities? Such as the company S is able to identify that is in disadvantage comparing to its competitor, R is also able to see that detains an advantage against S that improve its condition. Due to the available information in the market and the different levels of profits that each cost structure in the market is able to provide, R is willing to protect its advantage, and in order to do that, it incur in defence activities because they knew that it exists the possibility of company S spies.

The embodiment of defence activities in the model generates four possible outcomes, provided by combinations of defence activities of R and spying activities of S, as it it demonstrated in Table 4.1.

	R does nor defend	R defends
	$1-p$	p
S does not spy $1-p$	$(1-p)(1-q)$	$(1-p)q$
S spies p	$p(1-q)$	pq

Table 4.1: Espionage and Counter Espionage States and Outcomes

In spite of the decisions of R and S to incur in specific activities generate four different outcomes, it is only possible to observe two different states. This restriction of the set of identified states with possible repercussions for the value of the Industry and for the welfare of society is result from the absorption effect of intercept activities of R to the spy actions. As the espionage will not succeed if R also decide in defence operations, the success of S's activities only happen when the defence techniques are not available. Thus, the success of the of espionage activities is not only dependent on the quality of the spy instruments, but also is related with the failure of defence techniques.

$$p(1-q) \tag{4.10}$$

On the other hand, the failure in the collection of Rs cost advantage by S's espionage actions is result from the spy operations' flop, *i.e.*, the methods or techniques used for spying did not meet the identification of R's advantage, even when the defence techniques were not used, or even the outcomes that highlight the existence of counter-espionage methods, independent of the S' decision to incur in espionage. Thus, the success on the maintenance of cost advantage in R's production method is given by the sum of three distinct outcomes, as it is presented in Equation (4.11).

$$(1-p)(1-q)+(1-p)q+pq=1-p(1-q) \tag{4.11}$$

Therefore, the success on the acquisition of R's efficient vantage of production and their joining in the productive process of S no longer depend only in the positive outcome of spy actions, but also in the lack of success of counter espionage actions of R. This new factor to take into consideration by S will impact the proportion of each state in the value of this company, once it depends on the level of *penetration rate*, p, but also on the *interception rate*, q.

$$\begin{aligned} V_q &= \max_{T\geq 0, 0\leq p\leq 1} \qquad (4.12) \\ E &\left(\int_{t=0}^{\infty}\left((1-p(1-q))\frac{(a-c-\delta)^2}{9b}+p(1-q)\frac{(a-c+\delta)^2}{9b}\right)Xe^{-(r-\alpha)t}-\frac{p}{1-p}z|X(0)=X\right) \end{aligned}$$

As it is possible to see in Equation (4.13), the value of S considers the value of profit flows generated by the existence or not of a gap in the cost's structure of both companies taking into account the state generated by the dynamics of espionage and counter espionage activities by R and S. This dynamics, combined with the Real Options Approach, modulate the introduction of defense tactics in the optimal efficient solution for the Timing in the Occurrence of Espionage and in the Optimal intensity of such actions. Based on the same process as before, as it is also mentioned in the Appendix B, the decision of S is based in a optimal timing and a optimal intensity of soy actions of:

$$X_q^* = \frac{9bz(r-\alpha)}{4\delta(a-c)(1-q)}\frac{\beta^2}{(\beta-1)^2} \tag{4.13}$$

$$p_q^*(X^*) = p^{**}(X^{**})=p^*(X^*)=\frac{1}{\beta} \tag{4.14}$$

As it is possible to see, comparing Equation (4.13) with Equation (3.20), relation with the common parameters remains the same, being the effect equal. However, the introduction of q brings a new effect or factor that shifts the optimal timing to incur in espionage. The rise of defence tactics by R delays the entry of spy actions in the interaction between both companies. Interestingly, the presence of this activities does not change the optimal quality or intensity of spy activities, as it also does not happen in the social approach on chapter 4.

The role of the government is introduced here. As the Government covers all the cost related with the defence activities of R, it does not exists any change in the social welfare, only in the efficient solution. In this way, the regulator intervene with the aim of delaying the positive decision of incurring in spy action until it is beneficial for the society. In order to do it, the state will finance the necessary amount of defence techniques that guarantee an specific level of interception rate able to equalize the optimal timing for S and the social timing to incur in such actions, *i.e.*, $X_q^* = X^{**}$.

$$q^* = \frac{3\delta}{8(a-c)} \tag{4.15}$$

The timing equivalence of both decisions allow a positive level of interception for the defence measures of R, but only dependent on the parameters related with the cost's structures and with the maximum disposition to pay by the consumers. A positive increment in any parameter related with the costs of both structures, c and δ, will boost the optimal level of interception, *i.e*, the higher the advantage cost of R, higher will be the predisposition of R and the government to defence its secret or higher will be the means used to do it. On the other hand, an increase in the marginal cost of the industry will also rise the defence barriers of R. However, an improvement in the demand's condition to pay a higher price, *i.e.*, the consumer are able to pay a higher price when the supply is insufficient, leads to a negative shift in the optimal level of counter-espionage activities.

4.3.2 Consumption Subsidy

In the last section, we present a possible government intervention in the market *via* producers, promoting the defence of R's cost advantage. Based on the maximization of social welfare, the regulator might be more interest with a intervention on the side of consumers. This kind of intervention only produce indirect effect on the competition of both companies in the market and in the level of competition, with the subsidization of the products of a specific company. The green subsidies of the different government budgets in the world are a example of this situation, as it is the subsidization of solar panels in Portugal until 2009, the public assistance in the acquisition of electric cars in California and Thailand[5].

As the regulator wishes to delay the entry of espionage activities in the decision of

[5] http://www.latimes.com/business/autos/la-fi-hy-ev-state-subsidies-20170720-story.html

S, the government intercedes in favour of promoting the market's demand, and boosting the total amount demanded by the consumers, which mitigate the risk supported by S. With this higher level demanded in the market, the produced output of S increase, which guarantees a larger profit flow for the company, which may favour the application of funds in R&D and postpone the spy solution.

Public subsidization, in general terms, is a major mechanism used by the government in order to promote incentives in different markets (Schwartz and Clements, 1999). Although, the massive use of these instruments, either in producers or consumers, might produce substantial opportunity costs for the regulator and other agents in the market. The concept of subsidy or incentive powered by the government defines the public assistance on the *two sides* of the market, by providing better conditions in the market for the consumers through lower purchase of products and services with a lower price than it was verified in the competitive private market, or by the raise of producers' welfare to values that is not possible without public intervention (Schwartz and Clements, 1999). This incentives might by compose by explicit or implicit elements.

Based on the definition, subsidizing the consumers preferences compasses any intervention of the State that distort the full cost of the production of such goods or services by the producers R and S. Based on the subsidy categorization provided by Schwartz and Clements (1999), the distortion of the costs and subsequent reduction of the price for the consumers is only possible with direct government payments to consumers (cash subsidies or cash grants) or by regulatory subsidies, that consist in implicit payments based on the regulator's actions that alter the markets price or the access of information.

But why subsidize? Why the government might be interest in such intervention? Economically, the public intervention promotes the efficiency and the economic justice in the dynamic context of the market (Schwartz and Clements, 1999). This assistance is accomplished by the reallocation of resources that shift the preferences of the consumers and its behaviour, as well as the level of production of enterprise. The counterbalance of market imperfections, the promotion of economies of scale and the reach of social policy objectives (protections of of the most deprived, income's distributions and higher level of employment)are the three major reasons of public assistance (Schwartz and Clements, 1999).

The demand's subsidization by the government changes the preferences and the choices of consumers, which is crucial in order to achieve a better solution for the society. With the aim to analyse the impact of consumer's subsidization, the demand function, previously indicated in Equation (3.1) needs to incorporate the government intervention. This intervention is materialized through the parameter t, that mensurates the relative amount that subsidy covers in relation to the market's price, P. In other words, t

translates the percentage of the market's price that is subsidized. A larger value of this parameter indicates a higher intervention of the state in this industry. The extreme case of full subsidization[6], it might indicate the entire subsidization of this activity or also the government production of such services. The Equation (4.16) presents the demand preferences of the market's consumers, as well as the intervention of the government.

$$P_t = \frac{a - b(Q_S + Q_R)}{1 - t} \tag{4.16}$$

According to Equation (4.16), the preferences of the consumer is now dependent of another factor, the level of government assistance in the market t. The rise of the public intervention might lead to a higher willing to support larger market prices. Although, the direct participation of the Regulator in the market also alters the profitability of both companies, even when is is not yet decided the use of spy actions.

	Unsuccessful Spy Action	Success Spy Action	Espionage Impact
Occurrence's Probability	$1-p$	p	
Output Produced by S	$\frac{a-(1-t)(c+\delta)}{3b}$	$\frac{a-(1-t)(c-\delta)}{3b}$	$+\frac{2\delta(1-t)}{3b}$
Output Produced by R	$\frac{a-(1-t)(c-\delta)}{3b}$		$-\frac{\delta(1-t)}{3b}$
Market Price	$\frac{a+(1-t)(2c-\delta)}{3}$	$\frac{a+2(c-\delta)(1-t)}{3}$	$\frac{-\delta(1-t)}{3}$

Table 4.2: State Contingent Cournot-Nash Duopoly Outcomes for each state of Espionage Activities' results with Public Assistance

As it is possible to see, the intervention of the State brings the same effect of the spy decision, but *diluted* with a new agent that is able to boost the performance of the market. With a larger intervention of the Government, which is translated in this case in a larger t, the market price decrease to the consumers, which lead to a larger willingness to buy this products.

But, even with a subsidization of the activity of both companies, what should be the decision of S in relation to the occurrence of spy activities? The timing and the optimal level of penetrating in R is, in these circumstances, vulnerable to the higher-efficient level of the production of R, but also the level of Public presence. Based in the same methodology that was present before, the optimal timing to incur in Espionage Activities

[6] t equals 100% of the price.

by S and the optimal level in a context of market's subsidization is given by[7]

$$X_t^* = \frac{9bz(r-\alpha)}{\delta(a(4-t)+t(5ct-c+3\delta(1-t))-4c)}\frac{\beta^2}{(\beta-1)^2} \tag{4.17}$$

$$p_t^*(X^*) = p_q^*(X^*) = p^{**}(X^{**}) = p^*(X^*) = \frac{1}{\beta} \tag{4.18}$$

Based on the Equation (4.18), it is possible to identify resemblances with the Efficient Solution of S in Equation (3.20), but with a complex effect of the Public Intervention, t. This does not yield a singular effect on the Value of the Optimal Timing to incur in Espionage, as we will analyse further. Once again, the Presence of the Government in the Market does not possess any effect on the optimal intensity of espionage actions, which meets the solutions founded before in Equation (4.7), Equation (3.21) and Equation (4.14).

As it happen in the last section, the intervention of the Regulator directly impose the postponement of the optimal timing of S until it is optimal to the Society. In order to do that, the Government *enters* in the market, with a subsidization of the consumers in a exact measure that guarantees the efficiency of its activity and the equality of the Social and S's Optimal Timing, based on Equation (4.6) and Equation (4.18). Thus, the endogenously level of t that is given by $X_t^* = X^{**}$ is equal to:

$$t^* = \frac{(a-c-3\delta)}{10c-6\delta} - \frac{\sqrt{(a-c)^2-6\delta(a+6c+\frac{27}{6}\delta)}}{10c-6\delta} \tag{4.19}$$

As we said before, the regulator attempts to meet the maximum level of welfare to the society. Although, this level of Welfare is achievable by the most efficient mean, *i.e.*, the government chooses the solution that is less-costly in order or achieve the same purpose, *ceteris paribus*. Opposite to what happen with the social level of interception, the effect of some the operative costs and vantage's disparities is quite complex to understand based on the analytical analysis of the Equation (4.19). Only the level maximum willingness to pay of the consumers demonstrate a identified positive effect, *i.e.*, as the consumers are willing to pay more for the goods and services of the market when the supply is scarce, the government apply larger subsidy margins in comparison with the market's price. The solution also might conclude that larger level income of the consumers or a more wealthier economy that guarantees a larger availability of the consumers to pay a higher price for the goods, *ceteris paribus*, is followed by larger level of public subsidization.

[7]For further detail, see section B

4.3.3 Numerical Example

The relation between the role of R and S in this market, as well as the entrance of the government with an active attitude change the situation of each agent in the market. The consumers and the suppliers, with the efficient solution developed in the chapter 3 does not acquire the maximum level of welfare. The demand for the efficiency by the companies leads to a sacrifice of the social equity and utility of all agents in the market, in aggregate terms. Based in the same context of the section 3.3, we compare the solution efficiently optimum for S and R, as well as the best solution for the consumers and producers.

Taking into consideration the parameters' assumptions of Table 3.3, the optimal espionage solution for S translates into a optimal timing and penetration level of:

Output	Value
X^*	5.26309
$p^*(X^*)$	0.79323

Table 4.3: Efficient Solution for the parameters present in Table 3.3

With the intervention of the regulator, the total surplus of the market denotes extreme importance, which change the dynamics of the market. In this way, based on the same assumptions, the social optimal timing for S to incur in espionage and the optimal level of quality or penetration is equal to:

Output	Value
X^{**}	5.57678
$p^{**}(X^{**})$	0.793238

Table 4.4: Social Optimal Solution for the parameters present in Table 3.3

Comparing the results of Table 4.3 and Table 4.4, it is possible to identify the early introduction of espionage activities by S in the efficient environment, but with a similar level of quality of espionage instruments. These conclusions also were observed in the theoretical analysis of the model. However, in terms of welfare, the efficient solution grants a lower level, even in singular terms, for the consumers and producers, even in aggregate terms. The implementation of a social optimum, with the postponement of espionage activities with a similar level of penetration improve the social situation. As we can see in the Table 4.5, the incremental rise of the surplus is even greater for the suppliers than for the consumers.

	Efficient Solution $(X^*, p^{**}(X^*))$	Social Efficient Solution $(X^{**}, p^*(X^{**}))$	Incremental Variation $\Delta_{X^{**}-X^*}$
Consumer Surplus - CS	602.563	638.478	35.9144
Producer Surplus - PS	607.46	643.667	36.2062
Social Surplus - W	1210.02	1282.14	72.1206

Table 4.5: Consumer, Producer and Social Surplus for the parameters present in Table 3.3

In order to implement this social equilibrium, the regulator should actively intervene in the market because, in case of passive behaviour of this agent, the solution that will be established in the market will be the efficient, once it is more beneficial for S. As we see before, with the aim of approximate both timings, the efficient and social, the Government might use consuming subsidies and/or provide counter espionage or defence techniques to benefit of R. Both solutions direct influence the efficient timing, delaying the decision of S to incur in espionage and intervene in both *sides of the market*.

In what respects to the investment in defence techniques, the use of this instrument will guarantee a protection of the advantage of R, which translates in a more harmful situation for S. In this way and based in Equation (4.15), the government, in order to delay the entrance of espionage activities by S, should provide a total set of defence instruments that accommodate a *interception rate* equal to 5.625%. Comparing with the optimal value of *penetration rate*, the level of defence provided to R by public assistance is much lower. It also should be noted that, as we said before, the rise of the protection of the cost's advantage of R is provided by the government, which will not bring any additional cost of R. Also, these total set of techniques that guarantee a rise of the safety of R delays the expected possibility of S to successfully acquire the advantageous processes in its own productive process.

Output	Value
X_q^*	5.57678
$p^*(X_q^*)$	0.793238
$q^\star$	0.05625

Table 4.6: Defence Optimal Solution for the parameters present in Table 3.3

The possibility of direct intervention of the government is not only achievable by the suppliers assistance. By the *side of consumers*, the regulator might subsidize the consumption of goods or services available in this specific market. As we refer in the previous chapter, this theoretical assumption might also be sustained by the examples that are present in the reality. Similarly to what is clear in the public contribution to the larger defence of R, the consuming subsidy acts in the delaying of the efficient solution until the moment that is optimal for the Society the concurrence in espionage activities. Based on Equation (4.19), with the aim of directly actuates in the delaying of espionage activities, the government should provide, based in the efficiency of its operations, a subsidy equal to 7.43617% of the market's price that vigorates[8].

Output	Value
X_t^*	5.57678
$p^*(X_t^*)$	0.793238
$t^\star$	0.0743617

Table 4.7: Optimal Solution for the Consuming Subsidization, based on the parameters present in Table 3.3

As we said before, the influence of t to the optimal level of efficient espionage is not linear, as we might see in Equation (4.18). Based on the assumptions for the different parameters, in a first stage, *i.e.*, for values of subsidization lower than 25.1773% of the market price, the subsidization positively influences the timing of efficient penetrate in company R, in favour of the social interests. In other words, the public assistance in the consumers' purchase delay the efficient decision of S to spy. On other hand, to value superior to 25.1773% the relation between the X^* and t is negative, *i.e.*, possible rises of the subsidization of the demand directly contribute to a early implementation of spying techniques of S.

In what concerns to the influence in the optimal proportion of the price subsidized by the regulator, Figure 4.3 and Figure 4.4 demonstrate the effect of productions costs and disparity between the companies in t^*. In the first case, as we see before, the rise of the production cost implies a lower subsidy of the government in this market. On the other hand, the larger cost's advantage of R against S will imply a larger subsidy of the state, once S is in a more critical situation.

[8]The emphasis on the efficient operations of the government accrue on the double solution to equalize both timings. Although, one of them guarantee the same result with lower costs for the government.

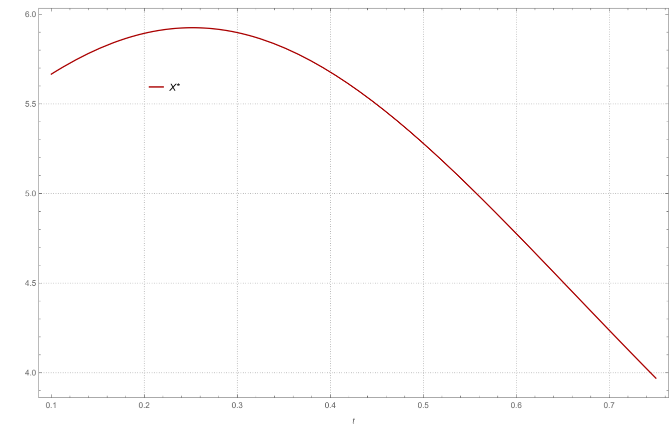

Figure 4.2: Evolution of Optimal Timing to incur in Espionage by S based on the values of t

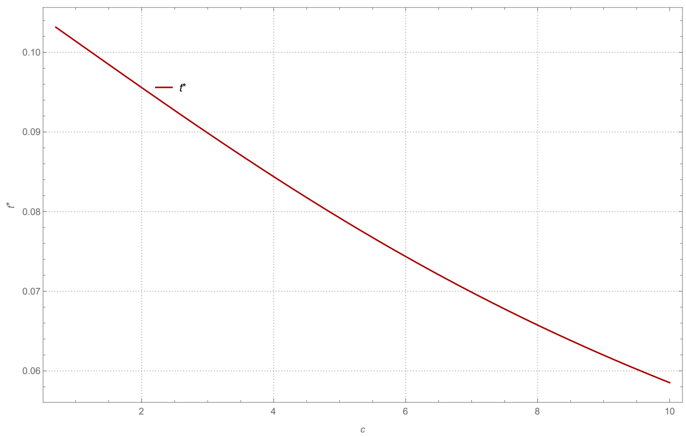

Figure 4.3: Evolution of Subsidy t^* based on the values of c

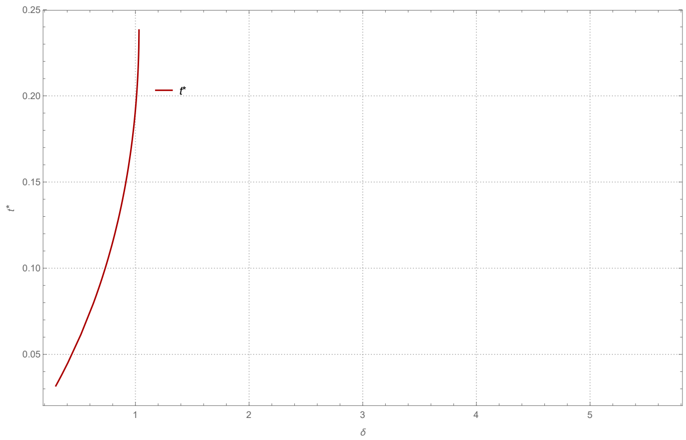

Figure 4.4: Evolution of Subsidy t^* based on the values of δ

Chapter 5

Conclusions

The purpose of this study was to develop a model able to incorporate the managerial decision of the enterprise to incur in espionage activities, based on the Real Options Approach.

Empirically, the operations of corporate espionage are becoming each time more frequently. The global competition, the political turmoil, the uncertainty about the future are some concerns that are taken into attention for the enterprises, in the moment of choosing which strategy should perform. The uncertain but irreversible consequences of spy activities after its fulfilment and the flexibility of the managers to realize such actions validate the use of Real Options Approach as method for our model.

The model implemented in this dissertation takes into consideration the unfavourable position *ex ante* of the spied against the competition, once the structure of the production are more expensive than the competition. The use of these activities comes as a solution for the enterprise to increase its value and to be at *the forefront of the market*.

In the first stage, we implement a model based on the individual decision of the company, concerned about the maximization of its value in the future. The use of spying activities implies a *trade-off* between the costs of such action and the benefits of the information acquired. Secondly, the efficiency of such decision will not lead to a larger social equity in the market, *i.e.*, the welfare of the society was compromised by the positive decision of optimally incurring in espionage by the spied, both in timing and *penetration rate*. In this way, it was necessary the introduction of a different agent, the government, able to regulate the market and secure the interest of the consumers and suppliers. Thus, the model predicted in the second stage had as purpose the maximization of the social welfare, instead of the value of an individual firm.

Although, the disparity between the efficient and the social optimal timing created advantages for the company to opt for efficient solution, regarding the interests of the society. It was necessary an active attitude of the Regulator, *via* implementation of instruments able to equalize efficiency and equity. To achieve this balance, it was implemented two different measures, in both *sides* of the market, namely the public assistance of defence techniques of the firm spied and the consuming subsidization. The intensity of these instruments guarantee the equality for the lowest possible cost.

The results of both models are conclusive. The cost structure of the production and spying activity, as well as consumers' preferences only influence the optimal time to incur in spy actions. In other words, the growth of the industry's costs of production and also the costs of espionage leads uniquely to the postponement of espionage activities. The intensity or the probability of successfully acquire information, captured by p, only is influenced by the risk of the market. The rise of the uncertainty surrounding the market anticipates the performance of these activities, but with a lower intensity and successful probability of obtaining the cost-advantage of the competition. The empirical evidence might indirectly corroborate such conclusions, once the high-tech industry, as well as others which are characterized by a larger level of uncertainty detain a larger level of registered actions of espionage.

On the other hand, the difference in the production costs between the enterprises presented in the market, defined as δ in the model, negatively influence the optimal timing of incurring in espionage, *i.e.*, the greater the difference between the productions costs of the enterprises, greater will be the need of implementing such actions to bridge the costs' differences.

Comparing the social and efficient timing, the social interest are compromised by the early decision of spying dictated by the efficient solution. To protect the social interest, the government active intervene in the market, with the endogenous determination of the level of defence of cost advantage of the competition or the consuming subsidy implemented (based on the equivalence of social and efficient optimal timings of espionage). Relatively to the financing of the defence techniques, the rising of productions costs, as well as the costs' discrepancy between the companies imply a larger level if defence, captured by the *interception rate*, q.

Although, the influence of the costs structure is not similar when it is considered the subsidization of the consume. Captured by t, the proportion of the supported price by the consumers that is subsidized by the government depended positively from the production costs of the industry. In this way, the rising of production costs directly imply a lower level of subsidization of the market demand. But, the larger cost advantage in the market impose a opposite behaviour, *i.e*, the grater difference between the cost structure of the spy firm and the competition contributes to a larger proportion of the subsidy.

The larger contribution of the model for the managerial theory and practice comes with the social implications of espionage. Contrary to what happen in the previous literature, the implications of the espionage for society are not fixed. In other words, conditional to the timing when such actions happen, the occurrence of espionage might benefit or damage the social welfare. These position give a new perspective for the literature, complementing both positions defended, either in defence of the economic advantages of this activity or in opposition to them. Future Research over this topic might incide about the determination of the optimal level of investment required to perform such activities, as well as a extension of the model to an oligopolistic or perfect competition environment. The inclusion of private techniques or reputational costs for the the firm which perform such activities might also be another alternative for the future development of this model. Nevertheless, it would be interest the development of the study of these actions once the decision of incurring in espionage is always on the table for the enterprises.

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Appendix A

Efficient Model of Espionage

Costs-Environments for R and S

Non-Symmetric Costs

In case of non-success of espionage activities of S, both companies share a different cost structure, with S producing with larger costs, c, and R with $c - \delta$. Based on the inverse demand of Equation (3.1), the profit flow of both firms is given by:

$$\pi_R = Q_R(a - b(Q_S + Q_R) - (c - \delta)) \tag{A.1}$$

$$\pi_S = Q_S(a - b(Q_S + Q_R) - c) \tag{A.2}$$

Maximizing π_R and π_S in order to Q_R and Q_S, respectively, we are able to find the optimal output of R and S to any level of quantity of the other competitor.

$$Q_R = \frac{a - bQ_S - c + \delta}{2b} \tag{A.3}$$

$$Q_S = \frac{a - bQ_R - c}{2b} \tag{A.4}$$

Equalizing both optimal levels of output for any given production of the market, the optimal output in a equilibrium situation is given by:

$$Q_R = \frac{a - c + 2\delta}{3b} \tag{A.5}$$

$$Q_S = \frac{a - c - \delta}{3b} \tag{A.6}$$

Replacing both equilibrium levels of production in the Equation (3.1), the optimal price is given by:

$$P = \frac{a + 2c - \delta}{3} \tag{A.7}$$

With the establishment of the optimal market's price and level of output for both companies, the equilibrium profit flow for both companies is equal to:

$$\pi_R = \frac{(a - c + 2\delta)^2}{9b} \tag{A.8}$$

$$\pi_S = \frac{(a - c - \delta)^2}{9b} \tag{A.9}$$

Symmetric Costs

In case of success of espionage activities of S, both companies share a similar cost structure, with both companies producing to a cost of $c - \delta$. Based on the inverse demand of Equation (3.1), the profit flow of both firms is given by:

$$\pi_R = Q_R(a - b(Q_S + Q_R) - (c - \delta)) \tag{A.10}$$

$$\pi_S = Q_S(a - b(Q_S + Q_R) - (c - \delta)) \tag{A.11}$$

Maximizing π_R and π_S in order to Q_R and Q_S, respectively, we are able to find the optimal output of R and S to any level of quantity of the other competitor.

$$Q_R = \frac{a - bQ_S - c + \delta}{2b} \tag{A.12}$$

$$Q_S = \frac{a - bQ_R - c + \delta}{2b} \tag{A.13}$$

Equalizing both optimal levels of output for any given production of the market, the optimal output in a equilibrium situation is given by:

$$Q_R = \frac{a - c + \delta}{3b} \tag{A.14}$$

$$Q_S = \frac{a - c + \delta}{3b} \tag{A.15}$$

Replacing both equilibrium levels of production in the Equation (3.1), the optimal price is given by:

$$P = \frac{a + 2c - 2\delta}{3} \tag{A.16}$$

With the establishment of the optimal market's price and level of output for both companies, the equilibrium profit flow for both companies is equal to:

$$\pi_R = \frac{(a-c+\delta)^2}{9b} \tag{A.17}$$

$$\pi_S = \frac{(a-c+\delta)^2}{9b} \tag{A.18}$$

Optimal Efficient Solution

Previously, we denote $V(X)$ in Equation (3.4) as the value of S, dependent of the result of the espionage activities performed against R.

$$V(X) = (1-p)\frac{(a-c-\delta)^2}{9b}\frac{X}{r-\alpha} + p\frac{(a-c+\delta)^2}{9b}\frac{X}{r-\alpha} \tag{A.19}$$

However, S will try to optimally decide in respect to the level of *penetration rate*, p. Maximizing the difference between Equation (A.19) and the cost of espionage, presented in Equation (3.5) with respect to p, the optimal *penetration rate* for any timing X is given by:

$$p^* = 1 - \frac{3}{2}\sqrt{\frac{zb(r-\alpha)}{X\delta(a-c)}} \tag{A.20}$$

Based on the studies of Dixit and Pindyck (1994), the value of the option to invest is, in this context given by Equation (3.13), where β follows a positive behaviour, as it is defended in Equation (3.18). The value of the option previously refereed is result from a simplification imposed by the *ebsorbing condition* (Equation (3.14)). However, to determine the indifference situation of X^* for the determination of the optimal Value of S, it is required to employ to the remaining conditions, observed in Equation (3.15) and Equation (3.16).

$$F(X^*) = V(X^*) - K(z,p) \tag{A.21}$$

$$\left.\frac{\partial F(X)}{\partial X}\right|_{X=X^*} = \left.\frac{\partial V(X)}{\partial X}\right|_{X=X^*} \tag{A.22}$$

Substituting Equation (3.4) and Equation (3.5) in Equation (A.21) and Equation (A.22), in respect to X^*, the optimal timing will be given by:

$$X^* = \frac{9bz(r-\alpha)}{4\delta(a-c)}\frac{\beta^2}{(\beta-1)^2} \tag{A.23}$$

Replacing the optimal timing of S to incur in espionage (Equation (A.23))in the optimal *Penetration Rate* (Equation (A.20), the optimal level of espionage techniques for X^* is:

$$p^*(X^*) = \frac{1}{\beta} \tag{A.24}$$

Appendix B

Social Model of Espionage

Cost Environment and influence in Consumer, Producer and Total Surplus

Consumer Surplus

Based on Equation 4.1, the consumer surplus is directly influenced by the optimal level produced by R and S.

$$CS = \frac{b(Q_R + Q_S)^2}{2} \tag{B.1}$$

In this way, and based in a situation where S produces to a superior cost than R (S produces to c while R produces to $c - \delta$), we replace Equation (A.5) and Equation (A.6) into Equation (B.1) in order to achieve the optimal amount of consumer surplus with a non-symmetric structure of the costs in the market.

$$CS = \frac{(2a - 2c + \delta)^2}{18b} \tag{B.2}$$

On the other hand, when the market faces a symmetric constitution of the cost, *i.e.*, the success of the espionage activities of S allow the firm to produce to $c - \delta$, the same cost than R, the consumer surplus suffers a shift. In order to translate that, we substitute Equation (A.14) and Equation (A.15) into Equation (B.1).

$$CS = \frac{2(a - c + \delta)^2}{9b} \tag{B.3}$$

Producer Surplus

The producer surplus conceptualizes the total amount of value of the firms presented in the market, in each moment.

$$PS = \sum_{t=0}^{\infty} \pi_i, i = \{R, S\} \tag{B.4}$$

Based on a favourable cost situation for R, the producer surplus constitutes the sum of the profit flow of each moment of both companies. In this way, we replace Equation (A.8) and Equation (A.9) into Equation (B.4), that translates into the optimal producer surplus of the market when both enterprises present different production costs, with vantage for R.

$$PS = \frac{(a-c-\delta)^2 + (a-c+2\delta)^2}{9b} \tag{B.5}$$

In a opposite situation, the equality in the cost's structure of the market, the producer surplus, as it happen in the consumer surplus, change. In order to translate this modification, is is necessary to substitute Equation (A.17) and Equation (A.18) into Equation (B.4).

$$PS = \frac{2(a-c+\delta)^2}{9b} \tag{B.6}$$

Total Surplus

Previously, we refer that the total surplus of the society or the social surplus consists in the surplus aggregated from all the agents that intervene in this market. Based on the market assumptions of the model, the agents that perform a direct role in the market are the consumers and the producers, which guarantee the totality of the surplus. Thus, in a non-symmetric context, based on the structure of the production of S and R, the value of total surplus is formed by the sum of Equation (B.2) and Equation (B.5).

$$\begin{aligned} TotalWelfare &= ConsumerSurplus + ProducerSurplus \quad \text{(B.7)} \\ W &= \frac{(2a-2c+\delta)^2}{18b} + \frac{(a-c-\delta)^2 + (a-c+2\delta)^2}{9b} \\ W &= \frac{8\delta(a-c) + 8(a-c)^2 + 11\delta^2}{18b} \quad \text{(B.8)} \end{aligned}$$

On opposite situation, the equality of the costs for both companies allow a alteration of the total surplus, given by the new optimal amount produced by both companies. Based on Equation (B.3) and Equation (B.6), we are able to determinate the new level of the total surplus.

$$\begin{aligned} W &= \frac{2(a-c+\delta)^2}{9b} + \frac{2(a-c+\delta)^2}{9b} \\ W &= \frac{4(a-c+\delta)^2}{9b} \end{aligned} \tag{B.9}$$

Optimal Social Solution

As it was refereed for the value of the S in the chapter 3, the value of the social surplus also depend the expected result of the espionage activities. In this way, the success, connected with a *penetration rate* of p, leads to a cost's symmetric environment, while the failure, $1-p$, leads to the cost's advantage of R. In this way, the value of the social surplus equal to what is established in Equation (4.4).

In order to maximize the value of espionage activities, the regulator determinate the optimal social *penetration rate* that guarantee the maximum level of social surplus. To do that, it is necessary to maximize the difference between Equation (4.4) and the costs of espionage, Equation (3.5) with respect to p, in order to achieve the optimal social level of p to any level of X.

$$p^{**} = 1 - \frac{3\sqrt{2}bz(r-\alpha)}{\sqrt{b\delta X z(r-\alpha)(8a-8c-3\delta)}} \tag{B.10}$$

Based on the Real Options Approach, the value of the option to invest in espionage, present in Equation (3.13) is now calculated with $W(X,p)$ with deterrence of $V(X,p)$. Taking into consideration the boundary conditions, with exception to the *absorbing condition* (that is embedded in the definition of the nature of option to invest), it is necessary to determine the indifference level of X^{**}.

$$F(X^{**}) = W(X^{**}) - K(z,p) \tag{B.11}$$

$$\left.\frac{\partial F(X)}{\partial X}\right|_{X=X^{**}} = \left.\frac{\partial W(X)}{\partial X}\right|_{X=X^{**}} \tag{B.12}$$

Substituing Equation (4.4) and Equation (3.5) into Equation (B.11) and Equation (B.12), the social optimal timing, X^{**} is given by:

$$X^{**} = \frac{18bz(r-\alpha)}{\delta(8a-8c-3\delta)}\frac{\beta^2}{(\beta-1)^2} \tag{B.13}$$

Replacing Equation (B.13) in the social optimal level of p, the optimal *penetration* *rate* for the optimal timing for the society is equal to:

$$p^{**}(X^{**}) = \frac{1}{\beta} \tag{B.14}$$

Based on the value of Equation (B.13) and Equation (B.14), it is now possible to determinate the value of the social welfare produced by the social solution, through the substitution in Equation (4.4).

$$W(X^{**}, p^{**}) = \frac{z\beta(8(a-c)^2 + 8\delta(a-c)(\beta+1) + \delta^2(11\beta-3))}{(8a-8c-3\delta)(\beta-1)^2} \tag{B.15}$$

Possible Actions of the Regulator

Defence Tactics

The public assistance of the government to protect the activity of R comes with the rise of the defence techniques of the company, inputting a new parameter, the *interception rate*, q. With the introduction of this parameter, the only substantial change comparing with the model developed in chapter 3 is the weight of each scenario in the value of S. Therefore, it is necessary to weigh the success of espionage activities for $p(1-q)$ (replacing p) and the failure of such actions for $1-p(1-q)$ (that substitutes $1-p$).

$$V_q = \left((1-p(1-q))\frac{(a-c-\delta)^2}{9b} + p(1-q)\frac{(a-c+\delta)^2}{9b}\right)\frac{X}{r-\alpha} \tag{B.16}$$

Along side with the Value of S of Equation (B.16), the cost of espionage presented in Equation (3.5), allows the maximization of difference between both with respect to the *penetration rate*. In this way, the optimal level of p for any level of X in a context of defence of R is given by:

$$p_q^* = 1 - \frac{3bz(r-\alpha)}{2\sqrt{-b\delta(q-1)Xz(a-c)(r-\alpha)}} \tag{B.17}$$

Based on the boundary conditions that defines Real Options Approach in this context, as it happen social and efficient solution, it is possible to define the value of the option to invest and the indifference moment X_q^*.

$$F(X)_q = AX^\beta + \frac{(a-c-\delta)^2}{9b}\frac{X}{r-\alpha} \tag{B.18}$$

$$F(X_q^*) = V_q(X_q^*) - K(z,p) \tag{B.19}$$

$$\left.\frac{\partial F(X)}{\partial X}\right|_{X=X_q^*} = \left.\frac{\partial V_q(X)}{\partial X}\right|_{X=X_q^*} \tag{B.20}$$

Replacing Equation (B.16) and Equation (3.5) in Equation (B.19) and Equation (B.20), it is possible to determine the optimal timing in defence context, X_q^*.

$$X_q^* = \frac{9bz(r-\alpha)}{4\delta(a-c)(1-q)}\frac{\beta^2}{(\beta-1)^2} \tag{B.21}$$

With the optimal timing defined, it is now possible to determine the optimal penetration rate for X_q^*, by replacing Equation (B.21) into Equation (B.17).

$$p_q^*(X_q^*) = \frac{1}{\beta} \tag{B.22}$$

Consumption Subsidy

Based on the intervention of the state in the consumer's preferences that impose a new demand function, presented in Equation (4.16), the value of S and R is also dependent of t. In this way, in a context of non-symmetric costs, the value of both companies is given by:

$$\pi_R = Q_R\left(\frac{a-b(Q_S+Q_R)}{1-t} - (c-\delta)\right) \tag{B.23}$$

$$\pi_S = Q_S\left(\frac{a-b(Q_S+Q_R)}{1-t} - c\right) \tag{B.24}$$

Maximizing π_R and π_S in order to Q_R and Q_S, respectively, we are able to find the optimal output of R and S to any level of quantity of the other competitor.

$$Q_R = \frac{a-bQ_R+ct-c+\delta-\delta t}{2b} \tag{B.25}$$

$$Q_S = \frac{a-bQ_R+ct-c}{2b} \tag{B.26}$$

Equalizing both optimal levels of output for any given production of the market, the optimal output in a equilibrium situation is given by:

$$Q_R = \frac{a+(t-1)(c-2\delta)}{3b} \tag{B.27}$$

$$Q_S = \frac{a+(t-1)(c+\delta)}{3b} \tag{B.28}$$

Replacing both equilibrium levels of production in the Equation (4.16), the optimal price is given by:

$$P = \frac{(a-2ct+2c+\delta(t-1))}{3} \tag{B.29}$$

With the establishment of the optimal market's price and level of output for both companies, the equilibrium profit flow for both companies is equal to:

$$\pi_R = \frac{(a+(t-1)(c-2\delta))(a-c(2t+1)+\delta(t+2))}{9b} \tag{B.30}$$

$$\pi_S = \frac{(a-c(2t+1)+\delta(t-1))(a+(t-1)(c+\delta))}{9b} \tag{B.31}$$

In case of success of espionage activities of S, both companies share a similar cost structure, with both companies producing to a cost of $c-\delta$. Based on the inverse demand of equation (4.16), the profit flow of both firms is given by:

$$\pi_R = Q_R\left(\frac{a-b(Q_S+Q_R)}{1-t}-(c-\delta)\right) \tag{B.32}$$

$$\pi_S = Q_S\left(\frac{a-b(Q_S+Q_R)}{1-t}-(c-\delta)\right) \tag{B.33}$$

Maximizing π_R and π_S in order to Q_R and Q_S, respectively, we are able to find the optimal output of R and S to any level of quantity of the other competitor.

$$Q_R = \frac{a-bQ_S+ct-c+\delta-\delta t}{2b} \tag{B.34}$$

$$Q_S = \frac{a-bQ_R+ct-c+\delta-\delta t}{2b} \tag{B.35}$$

Equalizing both optimal levels of output for any given production of the market, the optimal output in a equilibrium situation is given by:

$$Q_R = \frac{a-(1-t)(c-\delta)}{3b} \tag{B.36}$$

$$Q_S = \frac{a-(1-t)(c-\delta)}{3b} \tag{B.37}$$

Replacing both equilibrium levels of production in the Equation (4.16), the optimal price is given by:

$$P = \frac{1}{3}(a - 2(t-1)(c-\delta)) \tag{B.38}$$

With the establishment of the optimal market's price and level of output for both companies, the equilibrium profit flow for both companies is equal to:

$$\pi_R = \frac{(a + (t-1)(c-\delta))(a - (2t+1)(c-\delta))}{9b} \tag{B.39}$$

$$\pi_S = \frac{(a + (t-1)(c-\delta))(a - (2t+1)(c-\delta))}{9b} \tag{B.40}$$

We denote $V(X)_t$ as the Value of S in a context of subsidization of the consume, dependent of the result of the espionage activities performed against R and the proportion of the price of the product that is supported by the government.

$$\begin{aligned} V(X)_t &= (1-p)\frac{(a - c(2t+1) + \delta(t-1))(a + (t-1)(c+\delta))}{9b}\frac{X}{r-\alpha} + \\ p & \quad \frac{(a + (t-1)(c-\delta))(a - (2t+1)(c-\delta))}{9b}\frac{X}{r-\alpha} \end{aligned} \tag{B.41}$$

However, S will try to optimally decide in respect to the quality of the espionage techniques used, based on the level of *penetration rate*, p. Maximizing the difference between Equation (B.41) and the cost of espionage, presented in Equation (3.5) with respect to p, the optimal *penetration rate* for any timing X is given by:

$$p_t^* = 1 - \frac{3bz(r-\alpha)}{\sqrt{-b\delta X z(r-\alpha)(a(t-4) + t(-5ct + c + 3\delta(t-1)) + 4c)}} \tag{B.42}$$

Based on Real Options Approach, the value of the option to invest is, in this context given by Equation (3.13). The value of the option previously refereed is result from a simplification imposed by the *absorbing condition* (Equation (B.43)). However, to determine the indifference situation of X_t^* for the determination of the optimal value of S, it is required to employ to the remaining conditions, refereed in Equation (B.44) and Equation (B.45).

$$\lim_{X \to 0} F_t(X) = 0 \tag{B.43}$$

$$F_t(X_t^*) = V_t(X_t^*) - K(z,p) \tag{B.44}$$

$$\left.\frac{\partial F(X)}{\partial X}\right|_{X=X_t^*} = \left.\frac{\partial V_t(X)}{\partial X}\right|_{X=X_t^*} \tag{B.45}$$

Substituting Equation (B.41) and Equation (3.5) in Equation (B.44) and Equation (B.45), in respect to X^{*_t}, the optimal timing will be given by:

$$X_t^* = \frac{9bz(r-\alpha)}{\delta(a(4-t)+t(5ct-c+3\delta(1-t))-4c)} \tag{B.46}$$

Replacing the optimal timing of S to incur in espionage (Equation (B.46))in the optimal *penetration rate* (Equation (B.42), the optimal level of espionage techniques for X_t^* is:

$$p_t^*(X_t^*) = \frac{1}{\beta} \tag{B.47}$$